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THE TWELFTH CONGRESS OF THE TRADE UNIONS OF THE USSR AND THE TASKS OF IRON AND STEEL WORKERS

V. A. Podzerko

Chairman, Central Committee of the Union of Workers of the Metallurgical Industry

The Twelfth Congress of the Trade Unions of the USSR made an appraisal of the work done by the Soviet Trade Unions in the past five years and outlined ways for a further enhancement of the part played by the Trade Unions in the administrative, economic, and social life of our country.

It was stressed in the report of the VTsSPS (All-Union Central Association of Trade Unions) and in the delegates' speeches that during the period covered by the report, and especially after the Twentieth Congress and the December Session of the Central Committee of the Communist Party of the Soviet Union in 1957, the Trade Unions improved their work, mobilized the masses for the fight for the growth of Socialist industry and for a further improvement in operating efficiency—the basis for a continuous rise in the material and cultural standard of the Soviet people.

Such measures as the new procedure for settling labor disputes, the statute on the rights of the FZMK, (Factory, Plant, and Local Committee) the reorganization of the work of factory meetings, and the decentralization of administration resulting in an enhanced role played by local organizations, were conducive to a more active functioning of Trade Union organizations, a better fulfillment of their duties as schools of management, schools of economics, and schools of communism.

The Trade Union organizations of iron and steel workers, while supported by the active members, had improved the form and method of work,day in day out, had improved the organization and leadership of socialist competition, and had attracted more and more factory workers and office workers to industrial management; thus, it was possible to disclose and make use of new potential productive capacities.

The continuous care of the Party for the development of the ferrous and nonferrous industry, the reorganization of industrial management and an enhanced role of trade union organizations in solving economic problems ensured a systematic increase in metal output. In the period between the Eleventh and Twelfth Congresses of the Trade Unions, the annual output of pig iron increased by 9.7 million tons, that of steel by 13.4 million tons, that of rolled product by 10.9 million tons, and that of iron ore by 10.5 million tons. This increase alone represents more than double the annual output of ferrous metals in pre-Revolutionary Russia.

Following the initiative of the leading establishments in the country—the Kuznetsk Metallurgical Combine and the Dzerzhinskii Works—iron and steel workers joined in the Socialist Competition for the fulfillment of the 1958 Plan ahead of time to mark the Twenty-first Congress of the CPSU. The iron and steel workers kept their word; they fulfilled the 1958 Plan in all branches of iron and steel production ahead of schedule and produced 544,000 tons of pig iron, 1,286,000 tons of steel, 1,270,000 tons of rolled and tubular products, and approximately 1,600,000 tons of iron ore over and above the planned output.

The selfless work of iron and steel workers was highly appraised by the Party and the Government. An annual event—"Metallurgist's Day"—was introduced by the decree of the Presidium of the Supreme Soviet of the USSR last year. In 1958, 180 metallurgists were awarded the highly valued title of Hero of Socialist Labor, and nearly 5000 men were awarded orders and medals.

The Communist Party and the Soviet Government continue to give their attention to a further improvement in working conditions, an expansion of living and social facilities and an increase in the financial outlay on social insurance. More than a million workers and technical and administrative personnel at iron and steel establishments have changed to a six and seven hour working day and a new remuneration system. This reform has been completely carried out at the establishments of the ferrous industry and is nearing completion at the establishments of the nonferrous industry.

The change to a six and seven hour working day has been carried out simultaneously with the reorganization of the remuneration system, accompanied by a substantial increase in wages, especially for workers in a low wage bracket. Thus, at the establishments in the Krivoi Rog Basin, the wages of the grade 1 workers increased by 61%, of the grade II workers by 41.5%, and of the grade III workers by 51.5%. The number of workers earning less than 600 rubles monthly has been reduced by two thirds.

The earnings of the workers in the iron and steel industry have increased by 14% on the average, and the percentage of the basic wages in the total earnings increased from 58 to 77%.

The Twenty-first Congress of the CPSU placed big and important tasks before the personnel of the ferrous and nonferrous industry. In 1965, 65-70 million tons of pig iron, 86-91 million tons of steel, 65-70 million tons of rolled product, and 150-160 million tons of ore should be produced.

Expenditure on the new construction and modernization of the establishments of the ferrous and nonferrous industry during the Seven-Year Plan will be higher than the total for the past 30 years. The modernization of existing works and the construction of large mechanized and automated units has been planned and this will contribute to a considerable improvement in working conditions and will facilitate work.

These and other measures, together with an extensive adoption of new techniques of individual innovators and whole teams, should increase the output per worker in the iron and steel industry by 51% in the next seven years.

Inspired by the resolutions of the Twenty-first Congress of the CPSU, our metallurgists have followed the initiative of the personnel of the "Zaporozhstal" Factory and Ust'-Kamenogorsk Lead and Zinc Combine and have joined in the Socialist Competition for the fulfillment of the production quota for 1959—the first year of the Seven-Year Plan—ahead of time. Every single establishment has undertaken to make a worthy contribution to the fight for building Communism. According to information (not yet complete), the metallurgical workers have undertaken to give the national economy 225,000 tons of pig iron, about 500,000 tons of steel, and 80,000 tons of rolled product over and above the planned quota in the current year.

The results of the work of the first two months and 20 days of 1959 show that the metallurgists are keeping their word and are fulfilling their undertaking honorably. In that period, 75,000 tons of pig iron, 130,000 tons of steel, and 80,000 tons of rolled steel and tubular product were produced over and above the planned quota.

In the forthcoming Seven-Year Period, at least one third of the total increase in pig iron, steel, and rolled steel output should be obtained by a more efficient utilization of existing metallurgical equipment. In this connection, the initiative of the personnel of the Magnitogorsk and Nizhne-Tagil Metallurgical Combines, in starting a competition for achieving the best results in the utilization of metallurgical plants and for an improvement in operating efficiency, is of great value. The Central Committee of our Trade Union maintains that this competition must be extended under the slogan "More Steel from Every Operating Plant" to all metallurgical establishments.

An important potential source of steel output increase is a reduction in defective product and in idling periods which represent a great loss to the national economy. At some factories the percentage of defective production is still substantial. At the metallurgical factories of the Dnepropetrovsk Economic Region, rejected steel from the open-hearth furnaces constituted 0.72% of the total steel output in 1958, i.e., twice as much as at Magnitogorsk. At several works the idling periods of open-hearth furnaces during the hot and cold repairs are approximately twice as long as at the Kuznetsk and Nizhne-Tagil Combines.

It must be pointed out that the extensive experience of the leading teams and individual innovators in the metallurgical industry is not adequately studied and introduced. In this respect, the Central Committee of our Trade Union has a great and serious responsibility.

Great help in the dissemination of new techniques was given by the All-Union Inter-factory Courses which, unfortunately, are not being arranged at present. We think that this proven method of study, evaluation, and dissemination of new techniques should be reintroduced and expanded. The Central Committee of the Trade Union, the GNTK and the Gosplan (State Planning Commission) of the USSR, should take the responsibility for organizing the courses and for the All-Union conferences of the individual branches of the metallurgical industry.

That new metallurgical plants are started on time is of great importance for the fulfillment of the metal output quota.

In 1959 alone, five new blast furnaces, eight open-hearth furnaces, seven steel-rolling mills, eight coke-oven batteries, and other plants should be built. However, there are already indications that the construction of some metallurgical plants, especially at mining and ore-treatment establishments, may fall behind schedule. The managers of some metallurgical establishments are not taking the necessary steps to ensure the delivery of equipment on time and this creates additional difficulties in the construction and erection work. The economic administrators of the establishments and the trade union organizations should give the constructors as much practical help as possible.

General headquarters, control posts or temporary commissions for checking the progress of construction, mobilizing labor, carrying out the erection ahead of schedule, and supplying materials for new projects ahead of the delivery dates must be set up at all new projects.

While carrying out the resolutions of the Twentieth Congress, the Trade Unions of metallurgical workers should renew their efforts to encourage the workers in their fight for the successful fulfillment of the Seven-Year Plan.

The Socialist Competition for the fulfillment of the 1959 plan ahead of time should be made even more extensive, and the remarkable efforts of teams and shock-workers of Communist labor should be given all possible support.

The Trade Unions should continue to encourage the active participation of the working class in industrial development, to attract wide masses of workers to

industrial managements and continuously to improve the activities of permanent industrial conferences.

The Congress stressed the need for improvements in safety in industry, for the fulfillment of plans with regard to housing facilities, the distribution of living quarters, the operation of commercial enterprises, and the problem of food supplies.

The Congress paid special attention to the educational work of the Trade Unions among workers.

The Twentieth Congress of Trade Unions was a clear demonstration of an invincible solidarity of Soviet Trade Unions and the whole nation around the Communist Party, and of their willingness to put every effort into achieving the great tasks of extensive Communist industrial expansion.

MORE AUTOMATION IN INDUSTRY

One of the main tasks for 1959-1965, placed before the Soviet Metallurgist by the Extraordinary Twenty-first Congress of the CPSU is the problem of a further introduction of automation into metallurgical processes. The use of automatic methods will make it possible to increase operating efficiency substantially, it will relieve the operating personnel of arduous work under difficult conditions at metallurgical plants, it will improve the utilization of plants and the quality of products and it will lower the cost of production.

It is now essential to pass from the automation of individual operations to fully automated metallurgical processes, to set up fully automated sections and plants, and subsequently complete works. At present, about 90% of the pig iron and steel in the USSR is made in modern, mechanized, and automated blast furnaces and steel-making furnaces. At some works the operating of the scale cars of the blast furnaces has been automated, and the temperature control at the majority of open-hearth furnaces has been automated too. Highly efficient and fully automated rolling mills have been developed.

As pointed out by N.S. Khrushchev in his speech at the Twenty-first Congress of the CPSU, the introduction of automation is not only of economic but also of great social importance. In automated production, the character of work changes, the cultural and technical standard of workers is raised, and the prerequisites for the elimination of the difference between intellectual and manual work are created. The man in automated industry controls the technological process by setting up the program for the operation of the machine.

In the USSR the design and introduction of instruments and means of automation for the ferrous industry is not restricted to specialized organizations only; at several works there are integrated teams, and at some establishments there are complete shops, which are engaged in the development and introduction of automation. Thus, for instance, at the Pervouralsk Novotrubnoi Factory, a special shop—a laboratory for the mechanization and automation of industrial processes—has been set up. The laboratory personnel carried out a full automation of two tube-rolling mills, resulting in a substantial increase in output and a saving of approximately 3,000,000 rubles.

The staff of one of the largest metallurgical combines in our country—the Magnitogorsk Combine—developed a complex plan for the automation of industrial processes to be carried out in five—seven years. Several main operations at the shops of this combine were automated a long time ago. The plan envisages a further development of automation. According to calculations, the plan, when carried out, will result in savings amounting to 270-280 million rubles and an increase in operating efficiency by 60%, and it will release about 6000 workers who will be employed at other sections of the Combine. The expenditure on the automation will be recovered in the course of 1.5-2 years.

In his speech at the Twenty-first Congress of the CPSU, L.I. Brezhnev pointed out that although the utilization of blast furnaces and open-hearth furnaces in the USSR is 25-30% better than in the USA, the output per worker is lower. This fact is explained by a large number of workers engaged in auxiliary, maintainance, and secondary duties. In the development of schemes for full automation and mechanization, one must take into account the need for the mechanization of these duties since otherwise it will not be possible to increase the output per worker.

In particular, the mechanization of loading and unloading operations at metallurgical works is of great importance. 45-55% of all the workers engaged in these operations are employed at the internal transport system at the works, and up to 40% of all expenditure on main production consists of transportation costs. Therefore, the introduction of continuous methods of conveying materials is of great importance. This method has already been introduced at the Cherepovets Metallurgical Factory and in spite of some design defects has justified itself.

An important role in the mechanization of the transportation of loose, dust-containing and hot materials is played by tube conveyors. The introduction of conveyor systems will make it possible to reduce capital and operating costs substantially and to reduce the personnel engaged on loading.

The mechanization and automation of finishing, sorting, grading, and marking operations of final rolled product is of great importance. At the Magnitogorsk Metallurgical Combine approximately half of all the workers in the rolling mills are engaged in these operations. It is obvious that the mechanization of the finishing operations will result in a substantial increase in the operating efficiency of the rolling-mill workers.

The advances in computing techniques open great prospects for full automation. The application of computing machines provided with memorizing equipment will make it possible to determine the optimum operating conditions and to maintain them at the required level without the attention of the foreman. These machines are already in operation at some metallurgical shops in the USSR.

All these measures call for the development of the industry producing instruments and means of automation. Unfortunately, the instrument manufacturers are still

far from satisfying the needs of metallurgists: the production of separate elements of automatic control systems is not yet organized. Many components have to be made by "semidomestic" methods.

The organizations which design new metallurgical establishments, shops, and plants must plan for an extensive introduction of automation. So far, they do not cope with this task satisfactorily. Systems for the automatic control of operating conditions are designed and introduced by special organizations or by factory personnel. The automation is carried out on existing equipment and this, naturally, requires modifications, lengthens the work on automation and affects the regular operation of the establishment.

Nevertheless, all these shortcomings can be put right. There is no doubt that Soviet metallurgists and instrument makers will overcome these shortcomings and will clear the way for the full automation of production processes.

The application of automation in the metallurgical processes is becoming more and more extensive. A further development of the automation of industry is forcibly dictated by the development laws for the whole national economy. Therefore, the resolutions of the Twenty-first Congress of the CPSU envisaged the establishment of more than 50 experimental and model establishments where the most modern schemes for full automation will be applied. This will undoubtedly assist in the introduction of new, highly effective systems of automatic control.

Making use of scientific achievements and the advanced technique of our works, and working incessantly on production problems, Soviet metallurgists will successfully carry out the task of the automation of metallurgical processes.

COMPUTING MACHINES CONTROL PRODUCTION PROCESSES

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Recent developments in computing technique have made it possible to apply automation to the process of solving the most diverse mathematical problems. The speed of the electronic computing machines reaches 20,000 operations per second and, hence, it is now possible to solve problems which were previously regarded as insoluble because of the enormous amount of calculations. Since the machines comprise "memory" equipment it is possible to store a multitude of data fed into the machine and to store the results of processing these data. An appropriately programmed machine can control a technological process, plan production, determine and set up the most efficient operating conditions of a plant, and so forth.

Computing machines are divided into analogue and digital computers. In the analogue computers the operations are carried out by means of voltages or currents of various magnitudes, and in the digital computors—by means of digits coded in the form of electronic pulses. The analogue computers operate on the principle of a logarithmic slide rule on which the values are represented by a corresponding length on the rule and the accuracy of the measurement depends on the accuracy to which the cursor can be set up. The digital computers operate on the principle of an abacus whose accuracy is, in principle, unlimited. The analogue computing machines have a relatively low accuracy and are used solely for relatively simple problems, since an increase in the number of components of these machines leads to a reduction in accuracy. The digital computers are more complex but they are more universal and flexible. They insure a very high accuracy of calculations irrespective of the number of components. The most simple and, so far, the most widely applied computing machines in the automatic control of production processes are the analogue computers.

The simplest element in the analogue computing technique is the automatic electronic potentiometer which is applied extensively for the measurement of thermal parameters. By slightly modifying its circuit one can adapt it for carrying out multiplication, division, involution, evolution, and other mathematical operations. Figure 1 shows the circuit of the potentiometer for division and multiplication operations. Voltage E_2 is applied to the termini of the potentiometer which, by moving the slider of the rheochord R_1, balances voltage xE_1 taken from the rheochord with voltage E_2. Voltage E_3 is applied to the second rheochord R_2 whose slide is rigidly connected with the slide of rheochord R_1. At equilibrium $xE_1 = E_2$, and voltage E_1 from the second rheochord is $E = E_3 \frac{E_2}{E_1}$. If voltage E_1 is made constant, the multiplication operation takes place, i.e., $E \equiv E_3 \cdot E_2$; at $E_3 = E_2$ the involution operation is carried out, i.e., $E \equiv E_2^2$. When, on the other hand, voltage E_3 is constant, then the division operation is carried out, i.e., $E = \frac{E_2}{E_1}$.

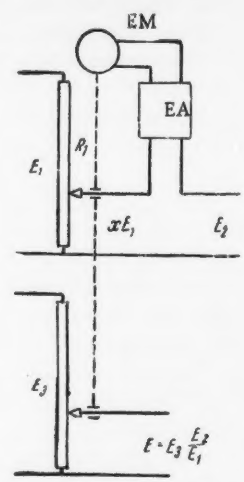


Fig. 1. Circuit of an electromechanical computer: EA) electronic amplifier; EM) equalizing motor.

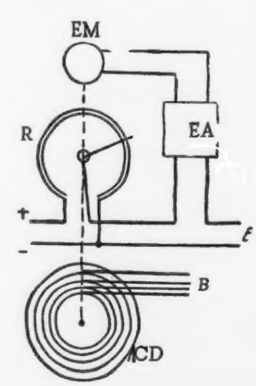


Fig. 2. Electromechanical converter of continuous values into digital: EA) electronic amplifier; EM) equalizing motor; R) rheochord; CD) coding disc; B) brush contacts

There are other more complicated circuits which can carry out mathematical operations involving variables, differentiation, integration, etc.

In the digital computing equipment the basic component is the part which has two stable positions (for instance, "on" and "off"). One of these positions is denoted by the figure 0 and the second by 1. Instead of the common decimal system, these machines employ a system based on the number 2 so that it is possible to represent large numbers by means of a small number of elements. Thus, for instance, to represent numbers from 1 to 511 one requires only nine components. Sets of elements comprise memory units, stored numbers and arithmetical arrangements for carrying out all arithmetical operations, which in effect constitute addition operations. The digital electronic computing machines are assembled from memory units and arithmetical equipment units. For a long storage of the results of calculations and the conditions of a problem to be solved, the computer is provided with a so-called "internal memory".

An important component of the digital computor is the equipment for feeding the data. Most of the variables of the technological process (pressure, rate of flow, temperature, etc.) are continuous magnitudes, and in order that the values of these variables could be fed into the computer they have to be converted from a continuous into a digital form. The most commonly used type of converter is the automatic electromechanical compensator (for instance, an automatic potentiometer), in which the slider of the rheochord is interlinked with the coding disc (Fig. 2). The magnitude measured (for instance, the emf of a thermocouple) is converted into the movement of the slider of the rheochord which is linked to an indicator or the pen of a recording mechanism. The coding disc consists of a commutator with a large number of segments over which the contact brusher slides. Each turning angle of the disc corresponds to a definite combination of the contacts between the brushes and the conducting segments of the disc. In this way, the voltage measured, e.g., the emf of the thermocouple, is transformed into a special code of voltages on the disc.

In some types of converters, the direct mechanical contacts are replaced by photoelectric circuits. The disc is then made transparent except for some opaque parts; a light source is placed on one side of the disc, and photoelements or photodiodes on the other. In addition to electromechanical analogue-to-digital converters there are various electronic converters which have no moving parts.

Digital computing equipment is extensively applied in the so-called systems of "scanning control". Modern complex, industrial plants are provided with a large number of instruments and their readings make it possible to evaluate the course of the technological process. Very frequently, however, it is difficult to take into account all the readings and to detect the deviation of the process from the normal course in time. In the scanning control system, the readings of the instruments are shown in the form of printed cards so that the control of the process is made much easier. The parameters to be measured are connected in a predetermined sequence by means of a special contacting device (usually of the step-by-step switch type) to the comparator and the converter. In the comparator, the parameter measured is compared with the predetermined limiting values and thus the deviation of the parameter from the normal conditions is revealed. After the parameter is converted to the digital form its value is automatically printed in the appropriate column of the table. If the parameter deviates from the preset limits, the operator is given a sound or light signal and the value of the parameter is printed in red in the table even before its turn. One of these machines (MARS-300) is designed to take 300 parameters and print up to 20 parameters per minute *

The system of digital scanning control can be applied in the metallurgical industry in coke and by-products works, blast-furnace shops, rolling mills, ore-beneficiation plants and other plants.

System similar to the system of digital scanning control are applied for recording and grading the products of rolling mills. The plants for the transverse cutting of steel sections are equipped with instruments which detect various defects in the section being cut (irregularities in thickness, internal gaps, etc) and with a control system which memorizes the defect in the plate after the strip has been cut and then controls the mechanism of the packing equipment so that good and defective plates are graded according to the type of defects. The acceptable and the defective plates are counted continuously. When the strip in coil is prepared for the customer, the automatic control machine prints a form for every coil and on it the lengths of good and defective section of the strip are indicated and the type of defect given.

The computing technique makes it possible not only to check production processes, but also to control them. Most of the processes can be described by a so-called complex parameter which is a function of the individual parameters of the process. It cannot be measured directly but it can be calculated. An example of such a complex parameter is the plant efficiency which is calculated by dividing one parameter by another. Similar parameters are production costs, power consumption per ton of product, percentage yield of acceptable product, etc..

Computing equipment can be used for evaluating complex parameters and for passing the results to the appropriate instruments. In this way, one can set up control systems which will automatically maintain a complex parameter of the process at a desired value by actuating controlling elements of individual parameters (pressure, temperature, etc.).

* This issue contains the article by V.A. Likhachev describing the RUMB, an automatic recording machine operating on the same principle.

In open-hearth steelmaking, a complex parameter is the total consumption of fuel oil, coke-oven and blast-furnace gases. To calculate the total input, the modern process-control systems comprise instruments which sum up the readings of several flowmeters and take into account the amount of air necessary for the combustion of each fuel. Depending on the calculated value of the total fuel input into the furnace, a corresponding amount of air is supplied.

A complex parameter in blast-furnace production is the output per minute as calculated from the heat balance and material balance. The output is calculated by a computing machine from the readings of several instruments which measure the temperature, pressure, and composition of the blast-furnace gas, and from several parameters whose values are assumed to be known and are fed beforehand into the computor. Such computing machines have been developed by the Donets Industrial Institute and the Lvov Polytechnical Institute for a blast furnace where a computing machine for calculating the heat balance of the zone of the direct reduction of ore by carbon was installed. Neither of the machines actuated separate regulating devices of the blast furnace directly but gave the blast furnace foreman infomation on the state of the process and the way of improving it.

For the calculation of a complex parameter, one must have its equation which would be continuously solved by the computing machine. Very frequently the equations for complex processes are not established with adequate accuracy and, therefore, it is necessary that a mathematica description of the process be automatically defined more accurately. If one of the coefficients which enter into the equation of the complex parameter can vary in the course of the process, i.e., it is a complex function of several controlled and noncontrolled parameters, then its value must be automatically determined by analyzing the effect of individual parameters on its value. This problem is solved either by means of the statistical analysis of the values of input and output parameters of the process subjected to the usual disturbances, or by introducing artificial disturbances. In both cases, the computing machine calculates and memorizes the accurate value of the coefficients and introduces these values automatically into the equation of the complex parameter.

The application of the computing technique makes it possible to forecast the course of the process on the basis of calculations, and hence one can determine the controlling actions beforehand and ensure that the input parameters of the process, including the complex parameters, would deviate from the preset value as little as possible. For instance, in the automatic control system of the screw-down mechanism of a reversible hot-rolling mill, the computer determines the moment when the driving motor has to be decelerated so that the screws can be stopped in the required position in good time.

The automatic control systems for the delivery of rolled steel from the rolls of the reversible mill (Fig. 3) are arranged in a similar way. The deceleration of the main drive should begin at the moment when the length of the part which has not yet been rolled is slightly shorter than the delivery path of the rolls so that a sufficiently low velocity of the rolled piece at the time of delivery is attained. The control system comprises two calculating machines: VU1 which calculates the lengths of the part to be rolled, and VU2 which calculates the delivery path of the rolls. When the difference between those two calculated values reaches a certain magnitude, the electronic relay, R, is actuated and causes the brakes to be applied to the main drive.

The high accuracy of the digital computing machines makes it possible for them to be used in digital servomechanisms. The preset movement of the system is then evaluated in the digital form by means of perforated cards, tapes or a magnetic plate with coded coordinates of the path changes in the system. These systems are extensively used for controlling metal-working machines and adjusting equipment. Frequently, the coordinates of the path of the system are presented in the form of equations. By solving the equations the computing machine continuously feeds the coordinates of the path to the servomechanism.

In the metallurgical industry, the digital servomechanisms are used in the programmed control of the screw-down mechanism of reversible hot-rolling mills. The screw-down mechanism is interlinked with the coding converter which provides for a description of the position of the upper roll of the mill in a digital form. The program for the adjustment of the screw-down mechanism according to passes is determined by means of a perforated card inserted into a so-called arithmetic unit. The coordinates of the holes in the card determine the code number which denotes the required adjustment of the screw-down mechanism. Electric signals from the arithmetic unit are passed to the control system of the driving motors, and thus, the movement of the screw-down mechanism in the required direction is ensured. The servosystem continuously compares the number corresponding to the required position of the screw-down mechanism with the number corresponding to its actual position obtained from the coding unit. Usually, the perforated card determines not only the program of drafts but also the speed schedule for the main drive as well as the schedule for the operation of the roller tables and manipulators, and in this way a full automation of the mill is achieved.

Programmed control with perforated cards is also used for the automatic adjustment of continuous hot-rolling and cold-rolling mills. For this purpose, the screw-down mechanism of the mill is provided with a digital-control servomechanism, and the speed regulators of the main drives are provided with digital adjusters. For the readjustment of the mill before a new section is

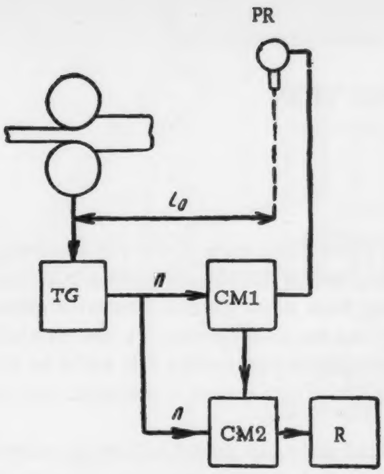


Fig. 3. Diagram showing the control system for the speed of the delivery of rolled piece from the mill rolls: PR) Photorelay for checking the progress of the rear end of the ingot; TG) tachogenerator changing the speed of the rolls; CM1) computing machine determining the length of the ingot part not yet rolled; CM2) computing machine determining the deceleration of the rolls; R) controlling relay of deceleration.

to be rolled, it is sufficient just to change the perforated card in the arithmetic unit.

At present, automatic control systems are generally designed for the stabilization of separate parameters of a process. Thus, for instance, there are regulators of temperature, pressure, flow rate, speed, load, etc., The control of modern industrial processes without such regulators would be quite impossible. In most cases, however, these controlled parameters define the process only if they are taken all together and a change in one of these parameters can very frequently be compensated by changes in other parameters.

The development of modern technological processes requires more and more instrumentaton for controlling very diverse parameters, and process control becomes very difficult since the course of the process has to be evaluated on the basis of readings of a large number of instruments. In addition, regulators with constant preset values do not ensure the optimum process conditions, since the preset values of individual regulators have to be changed if internal conditions (for instance, the raw materials) have been changed. Complex relationships between process parameters do not permit the operator to establish the optimum process conditions in time. All these problems can be solved successfully with the use of computing machines provided with digital scanning control systems.

If the equation for a given process is known with adequate accuracy, then the computing machine, appropriately programmed, continuously solves the equation and determines parameter values corresponding to the most efficient operation of the process. These values can be presented by the machine in the form of "advice" to the operator (tables) or in the form of a command for changing the position of individual regulators.

A computing machine can be used as a memory device. In this case, the machine studies the process on the basis of statistical analysis and accumulates operating data by memorizing the actions of the operator controlling the process. With the accumulation of operating data, the machine begins to fulfill the functions of the operator and gradually can replace him completely.

In addition to the control of technological processes, the computers can be used for controlling material supplies, organization and planning of production. Since the machine has an extensive storage capacity it can keep records of orders, material in stock, components which are in use in production, as well as the data on the growth and economics of production, etc. Since the results of all calculations are obtained from the machine almost without delay, the machine is in a position to take the best decisions regarding any changes which have to be introduced into production process under given conditions if any irregularity in production takes place.

THE AUTOMATION OF BLAST-FURNACE PRODUCTION

V.Yu. Kaganov

Central Laboratory of Automation

In the main, the iron and steel industry of the USSR is equipped with large-capacity, efficient blast furnaces. Approximately 90% of the total pig iron is made in mechanized furnaces which are provided with a number of automatic-control devices.

The most highly mechanized and automated section in the blast-furnace shop is the charging system. At the Kuznetsk and Nizhne-Tagil Combines, the operations on loading and weighing charge materials are automated too. The blast regime is automatically controlled at the majority of blast furnaces in the USSR. In addition, the furnaces are equipped with measuring and controlling instruments which allow the personnel to detect irregularities in furnace operation in time to take appropriate action.

The method of controlling furnace operation "from above" is widely applied. The furnaces are charged by means of mechanisms which automatically carry out the preset program for charging the materials into the furnace; at the same time, the foreman varies the weight of coke and ore rounds, the order of charging the materials into the furnace, the stock level, the composition of the charge and its distribution in the furnace top. The whole operation of the charging system is coordinated by the program controller who determines and checks the sequence of ore-and-flux and coke portions of the charge loaded into the skip, checks the movement of the skips of the main hoist, the charging of ore and coke, the opening of equalizing valves, the descent of large and small cones and the operation of the revolving distributor. The stabilization and control of blast parameters and other factors which influence the operation of the blast-furnace are widely applied together with the control of the blast furnaces "from above". The automation of the blast-furnace process is fairly extensive in the USSR (Fig. 1).

For measuring the flow rate of the cold blast, a flowmeter which incorporates arrangements for temperature, humidity and pressure corrections has been developed and successfully tested under industrial conditions. The design of apparatus for the automatic adjustment of the operation of the air blower depending on the temperature, humidity and barometric pressure of the inspirated air, has been completed. A two-way signal communication between the blast furnace and the air blowers is used for ordering the necessary amount of air.

One of the very important tasks in a further extension of automatic control in the blast-furnace process is the completion of the automation of the whole charging system by automating the operation of the scale cars and including them in the general automated system of charging, and the development of a new automated system of charging in which scale cars would be eliminated and replaced by a system of conveyors and scale hoppers.

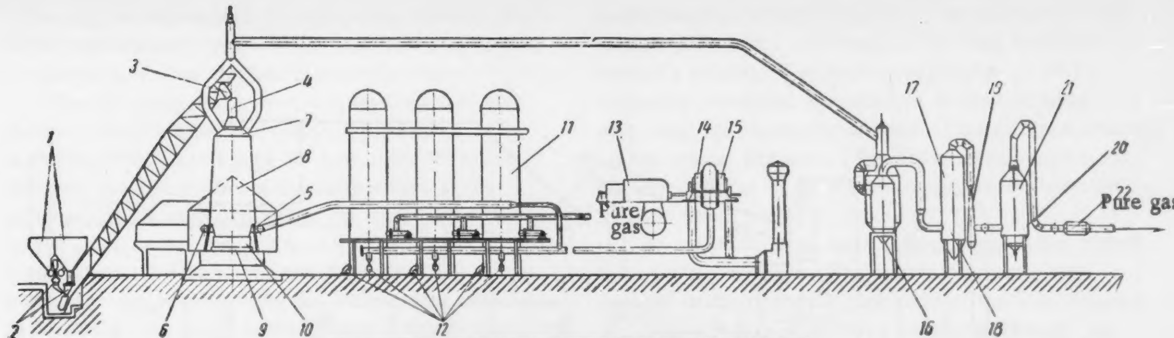
Automated scale cars should collect the materials from the bins, weigh them, travel along (including automatic starting, acceleration, deceleration and accurate stopping), unload the materials, and check the process of loading and weighing. At the Kuznetsk Metallurgical Combine, all control equipment is mounted on the scale cars. Communication with the ore and flux bins is effected by means of end switches set up at the lower part of the scale-car frame, and by guides on the track in front of the bins. When the scale cars pass the bins, the guides actuate the corresponding switches. There is a counter with a bar commutator for the control of bin loading. The acceleration, movement and stopping of the scale car is carried out automatically. The program for weighing the charge materials is set up on the scale head of the scale car with the use of a special contacting device.

The Nizhne-Tagil Metallurgical Combine has an automatic system for loading and weighing the charge in operation; the control instruments are installed in the foreman's control room and consist of special plug selectors. With the use of the plug selectors, the foreman determines the program for loading the materials from the bins into the scale cars. Work on the automation of the scale car movement is under way.

The full automation of the scale cars will make it possible to improve the charging operations of the furnace and will free the scale car operators who work under difficult conditions.

For a successful operation of automatic control it is necessary to have a constant quality of charge materials and stable operating conditions at the blast furnace. In practice, however, operating conditions at the blast furnaces can vary. The resulting irregularities in the distribution of the gas flow and in the temperature in the furnace must be eliminated by varying the method of charging, the conditions of the blast, and the ore burdening.

At present, these adjustments are carried out by the foreman who makes a decision on the basis of the instrument readings, the operation of the tuyeres, the temperature and analysis of the pig iron and slag, etc.



Nonautomated operation	1	4	6	10	15	16	18	21	
Partly automated operation	2	8	9	12	14				
Fully automated operation	3	5	7	11	13	17	19	20	22

Fig. 1. Diagram showing the automation of individual operations at one of our modern blast furnaces: 1) Filling the ore and coke bins; 2) scale car operation and coke delivery; 3) charge delivery; 4) control of the weight of the ore and coke charges and of the charging program, according to the parameters of the blast-furnace operation; 5) control of the temperature and humidity of the blast; 6) distribution of the blast to the tuyeres; 7) control of the gas pressure at the blast-furnace top; 8) control of the blast-furnace operation according to the pressure drop in the shaft; 9) delivery of the blast-furnace products; 10) control of pouring operations and the preparation of the runners; 11) control of the air-stove temperature; 12) change of the air stoves; 13) control of the operation of the air-blower turbine; 14) control of the blast rate; 15) control of the blast feed to the blast furnace; 16) removal of the blast-furnace dust; 17) spraying the packing in the spray tower; 18) periodic washing of the spray tower; 19) water input and pressure drop in the spraying pipe; 20) operation of the Cottrell precipitators; 21) periodic washing of the Cottrell precipitators; 22) gas pressure control in the gas washing plant.

In recent years, some work has been done on developing control systems interlinked with the technological process in such a way that when an irregularity occurs in the operation of the blast furnace, the setting of all the controlling equipment for individual parameters and the program of furnace charging are changed automatically and eliminate any irregularity in the operation. For the design of such a system, it is necessary to find a primary signal (or a set of signals) which describes the furnace operation and controls the factors which could eliminate any irregularity in the furnace operation most efficiently. This problem can be solved in the following ways.

1) By developing a computing machine which at any moment would solve a system of equations which relate the basic parameters of the blast-furnace processes analytically to the readings of the instruments, and would calculate the complex signal for controlling the blast-furnace operation.

2) By developing a computing machine which would determine the optimum operating conditions of the furnace on the basis of detailed instructions regarding the operation of the blast furnace and, by analyzing all the deviations from the optimum conditions, would calculate the type and magnitude of the controlling factor. Such a machine can "memorize" the conditions under which the furnace is operated most economically.

3) By developing a system of automatic regulating devices interlinked with the blast-furnace process and controlling it by methods which at present are widely employed in blast-furnace practice.

The Central Laboratory of Automation proposed a system of full automation for blast-furnace operation (Fig. 2) designed on the lines of the third version. The system is comprised of several computing instruments which determine the relationship between the factors which upset the normal course of the blast-furnace process, and the methods which restore normal operation. The system can be arbitrarily divided into four parts: 1) the control of the operating conditions of the hot blast; 2) the control of the revolving distributor operation; 3) the automatic change of the charging method; 4) the control of the blast-furnace temperature.

The operating conditions of the blast are controlled according to the pressure drop between the bustle pipe and the middle of the stock. The instrument which measures the pressure drop is connected to the computing machine, 1CM, which adjusts the regulators of the temperature, humidity, and rate of the blast accordingly. In addition, the introduction of an automatic distribution of the hot blast to the tuyeres, with the object of ensuring a uniform gas stream, is envisaged. The 1CM computing machine is also linked to the instrument which determines the speed of the descent of the charge materials. If the rate of the descent of the charge decreases and scaffolding and slips occur, then the operation of the blast regulators is adjusted accordingly. The instruments which measure the temperature in the tuyere zone and the temperature

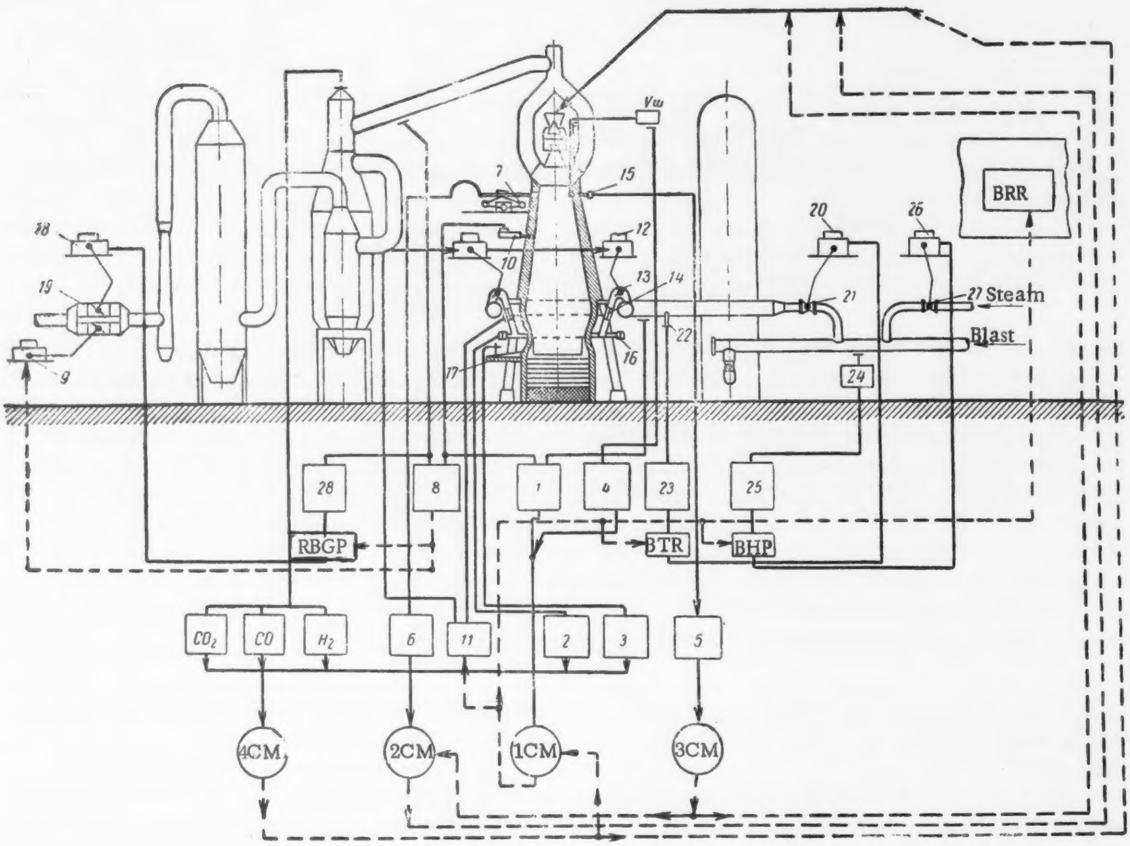


Fig. 2. Diagram showing the full automation of a blast furnace: 1) differential manometer for measuring the pressure drop in the lower half of the blast furnace; 2) instrument for measuring the temperature at the tuyeres; 3) instrument for measuring the temperature of the slag; 4) instrument for measuring the speed of the descent of the charge; 5) multipoint recorder for measuring the temperature on the periphery of the shaft; 6) instrument for measuring the temperature along the radius of the shaft; 7) probe for periodic measurements of the temperature along the radius of the shaft; 8) differential manometer for measuring the pressure drop in the upper half of the blast furnace; 9) servomechanism for an instantaneous lowering of the pressure in the blast-furnace top; 10) apparatus for measuring the static pressure; 11) equipment for the automatic distribution of the blast in the tuyeres; 12) servomechanisms for controlling the blast rate in the tuyeres; 13) controlling instruments at each tuyere; 14) instruments for measuring the blast rate through each tuyere; 15) thermocouples; 16) radiation pyrometers for measuring the average temperature at the tuyeres; 17) immersion thermocouple for measuring the temperature of the slag during the flushing; 18) servomechanism; 19) a component in the pressure control system; 20) servomechanism; 21) instrument for controlling the temperature of the blast; 22) thermocouple; 23) potentiometer for measuring the temperature of the hot blast; 24) sensing element; 25) instrument for measuring the humidity; 26) servomechanism; 27) valve for humidity control; 28) manometer for measuring the pressure of the blast-furnace gas; 1CM-4CM—computing machines; BTR—blast temperature regulator; BHR—blast humidity regulator; BRR—blast rate regulator (at the air-blowing plant); RBGP regulator for the blast-furnace gas pressure.

of the slag are linked with the computing macine, 4CM, which prevents an increase in the blast rate or a drop in its temperature when the hearth becomes cooler.

The operation of the revolving distributor of the charge is controlled by the computing machine, 3CM, according to the readings of the instrument (5) which measures the distribution of the temperature at the periphery of the shaft, below the top level of the stock. In this arrangement, the points of maximum and minimum temperature are determined and the controlling action method, aimed at decreasing the temperature difference between separate points at the furnace circumference, is selected. If this difference is not reduced in a certain period of time, the controlling pulse is fed into the computing machine, 2CM, which determines the sequence in which the charge materials are to be introduced. The distribution of the charge over the cross section of the furnace is controlled by changing the ratio between the number of rounds charged on the periphery and the number charged into the central part of the shaft. This ratio is determined by the computing machine, 2CM, according to the readings of the instruments(6) which measure the distribution of the temperature over the diameter of the shaft below the stock level.

The apparatus for measuring the temperature can be made in the form of a special beam with thermocouples mounted in it, or in the form of a probe (7) which is periodically moved along the radius of the shaft. The pressure drop in the upper half of the shaft (between the middle of the shaft and the blast-furnace top) is measured by means of the instrument (8) which adjusts the operation of the pressure regulator of the blast-furnace gas. If the pressure drop increases rapidly, the pressure at the blast-furnace top can be temporarily reduced by means of the servomechanism (9) and, thus, the stock can be made less compact.

The temperature conditions are controlled by the computing machine, 4CM, which determines the operation of the hot-blast temperature regulator and the ore burden for given conditions by changing the operation of the automatic scale car or the weight of the coke charge. The operating pulses for this machine are provided by the readings of the instruments which measure the temperature in the tuyere zone and the temperature of the slag, and also by the readings of the instruments which measure the content of CO, CO_2 and H_2 in the blast-furnace gas. A method of calculating the temperature conditions of the blast furnace from the results of the gas analysis is being developed in the Moscow Steel Institute.

Several elements of this comprehensive system of blast-furnace control are being tested at blast furnaces. Considerable difficulties were encountered in the design of an apparatus for measuring the static pressure in the middle part of the shaft. Not until recently were reliable measurements of this parameter realized, and thus it was possible to establish a method of blast control based on two pressure drops. A test showed that the principle of controlling the parameters of the blast according to the pressure drop in the lower half of the blast furnace is basically correct. The pressure regulators very frequently prevented irregularities in blast-furnace operation, and, on the other hand, if the foreman switched off the control and waited for further developments serious irregularities in the blast-furnace process inevitably took place.

At the same time, some shortcomings in the control system were revealed. The optimum pressure drop depends on the operating conditions of the blast furnace and should change when these conditions change. An increase in the pressure drop indicates not only an increase in the resistance of the stock to the gas passage but also that the hearth is filled with the products of the blast-furnace process. At present, the Central Laboratory of Automation is working on an improvement of this link in the control system; in particular, work is being carried out on investigating the possibility of controlling the operation not according to the absolute but to the relative pressure drops because they vary less when the operating conditions of the blast furnace are varying. To determine the effect of various factors on the pressure drop, methods of mathematical statistics are being applied and equipment for controlling and adjusting the parameters of the blast are being improved. Work has been started on controlling the distribution of the blast to the tuyeres. Unfortunately, the rate at which this work progresses is obviously too slow.

A system of controlling the operation of the revolving distributor is being tested at several works.*

In the course of the development of the system for a comprehensive control of the blast furnace operation, it became necessary to find new methods and means for measuring and controlling some parameters which describe the course of the blast-furnace process, i.e: the static pressure at various levels of the blast-furnace, the temperature in the tuyere zone, the temperature of the slag, the height and contour of the stock, the speed of the descent of the charge materials, and the composition of the blast furnace gases. The Central Laboratory of Automation is developing and industrially testing an ultrasonic apparatus for measuring the level of the stock, an apparatus for measuring the mean temperature in the tuyere zone and the temperature of the slag, an apparatus for the remote control of the air blower, and one for controlling the operation of the automatic scale cars.

Of especial interest is the development of standardized electric-type sensing elements for measuring the more important variables of the blast furnace process. The application of these devices in conjunction with a multipoint automatic typing machine RUMB, for numerical recordings, will make it possible to simplify the control

*An article by N.V. Mozhaev (this issue) gives a more detailed account of this work.

system of the blast-furnace process substantially. In addition, it now becomes possible to use the discrete-action computing machines for the blast-furnace process, and this opens new prospects for automatic control.

Extensive preparatory work must be carried out before a comprehensive system of the blast-furnace control is introduced. One must ensure that the properties of all the initial materials (the mineralogical and chemical composition, and size analysis of raw materials and fuel) which are charged into the furnace are as constant as possible; the mechanization of labor-consuming operations in blast-furnace shops must be completed and at the same time the future automation of pig iron and slag disposal, of the change of the tuyere equipment and of the pouring of pig iron should be taken into account; one must modernize and develop new equipment suitable for automatic operations (an automatic scale car and, later on, an apparatus for the continuous charging of materials, and an apparatus for the continuous mechanized sampling of charge materials).

It is essential to develop a method for the continuous automatic testing of pig iron and slag composition during pouring, for measuring the temperature of these materials in the tuyere zone, and for measuring the physical and chemical composition of the charge materials and the contour of the blast furnace; it is also essential to improve the method of taking gas samples and measuring the pressure at various levels of the blast furnace, and to develop a number of new automatic instruments for the determination of the contour of the stock and for gas analysis.

For the period between 1959-1965, the introduction of new automatic control methods at 33 new, and at all modernized, blast furnaces is planned. The complexity of this task calls for a serious revision of methods and means of automation and, therefore, the introduction of the main elements of the control system will have to be gradual. At first, reliable sensing elements for measuring new parameters will be developed, then control circuits will be designed, and only after successful testing will the automatic control be introduced. The individual units of the complex control system will be introduced as soon as they become available. The economic effect of the full-automation systems is difficult to estimate at present since there are no fully automated furnaces either in the USSR or abroad. Preliminary calculations, however, show that one may expect an increase in output by 1.5-2% and a reduction in coke consumption by 1-1.5%.

* * *

MEASURING THE STOCK LEVEL BY MEANS OF ULTRASONICS

Yu.Ya. Treister

Central Laboratory of Automation

The height and distribution of the charge in the blast-furnace top is one of the important parameters determining the blast-furnace process. At present, the stock level in the blast-furnace top is measured at two points by means of stock line indicators whose readings are not sufficiently reliable and accurate. This fact explains the search for new methods of measuring the level and contour of the stock in the blast-furnace top. Here we give a description of ultrasonic location methods which make it possible to determine the distance between the source of the ultrasonic waves and the surface of the stock by the time which elapses between the emitting of a pulse and the receiving of the reflected pulse.

The ultrasonic apparatus should detect the fluctuations in the stock level within the range of 1-5 m to an accuracy of 0.1 m at a blast-furnace gas temperature of 500-600°C, with a dust content of 50 g/cu.m and a counter-current blast.

The Central Laboratory of Automation has developed two types of ultrasonic level indicators: one with a gas-jet generator of ultrasonic oscillations and the other with magnetostriction generator.

A magnetostriction vibrator was used as the receiver.

In 1956, during the preliminary tests of the ultrasonic level indicators on a model of the blast-furnace top, it was found that the gas-jet generator with a revolving disc cannot be used in the space below the bells of the blast furnace because of the breakdown of the revolving parts. The magnetostriction generator* was found to

* The magnetostriction effect employed in the generator involves a change in the length of ferromagnetic bodies under the action of the magnetic field. The mechanical vibrations of the nickel plates of the vibrator produce elastic oscillations of air.

In the receiver, the reverse effect (i.e., the variation of the magnetic field in the ferromagnetic magnetized bodies when longitudinal forces are applied) is utilized. At the same time, electric oscillations are produced in the coil of the receiver.

be suitable and was operating normally in a range of 1.5-3 m at a high temperature (up to 300 °C) with a high dust concentration (up to 50 g/m^3) and counter-current air flowing at the speed of 2 m/sec.

It should be mentioned that the tests carried out on equipment of a similar type in England did not give positive results.

The ultrasonic apparatus was installed at one of the blast furnaces of the Dzerzhinskii Factory in 1957.† The power of the ultrasonic emission was increased to 2.5 times that of the experimental apparatus. With the object of improving the sensitivity of the reception and the stability of the operation, a polarization unit, supplying direct current to the vibrator, was introduced into the circuit.

Figure 1 shows a photograph of the vibrator unit. The joints between the vibrators and the flanges are sealed by means of heat-resistant silicone resin, SKT. At one end, the unit has threaded holes for mounting it on the supporting tube.

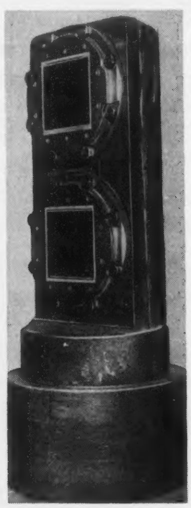


Fig. 1. Vibrator unit.

The circuit of the ultrasonic stock line indicator is shown in Fig. 2. The indicator, the self-recording pen, and the amplifier are mounted on the panel in the blast-furnace foreman's room. A special box with the apparatus (high-voltage relay, polarization unit and others) is mounted on the platform erected under the skip bridge.

The installation of the vibrators is shown in Fig. 3. A guide tube is welded to the blast-furnace shell, and a Schmidt window and a stopcock are mounted on the tube. A shutoff tube is placed inside the guide tube, the vibrator unit being attached to the shutoff tube by means of bolts. Cooling water and electric leads for the supply of the vibrator unit pass through the shutoff tube.

Figure 4 shows the recording diagrams obtained with the ultrasonic apparatus. The ultrasonic signals pass easily through blast furnace gas containing a large amount of dust. The counter-current stream of the blast has practically no effect on the operation of the ultrasonic stock-level indicator. When the furnace was under full blast and the stock level was 0.5-1.5 m (determined by ordinary stock-level indicators) the reflected signal from the stock was observed on the screen of the oscillograph (Fig. 4, I). The actual distance from the vibrators to the screen was 1.5-2.5 m. As the stock descended the signal became weaker and disappeared when the level of the stock was below 1.5 meters.

In addition to the main signal from the stock, interference signals, produced of course by the reflections of the signals from the charge particles thrown up by the gas stream, were observed. The interferences were short-lasting and irregular; hence, in future, it will be possible to adjust the apparatus in such a way that the false signals will be eliminated. When the high-voltage relay was switched off (the emitting signals were absent), the interference signals produced by the furnace operation

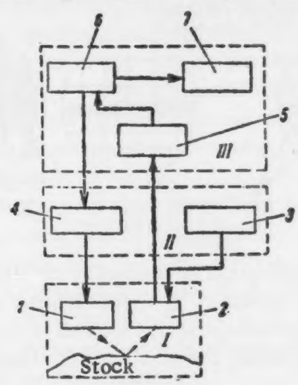


Fig. 2. Circuit of the ultrasonic stock line indicator: I) in blast-furnace: 1) emitting vibrator; 2) receiving vibrator; II) in the box at the blast-furnace top: 3) polarization unit; 4) high-voltage relay; III) in the foreman's room: 5) amplifier; 6) self-recorder; 7) indicator.

were observed on the oscillograph screen (Fig. 4, II).

When the large cone is lowered, the charge materials intersect the ultrasonic beam and produce interferences over the whole field of the oscillograph screen (Fig. 4, III).

In two months the operation of the vibrator in the space underneath the cones of the blast furnace showed

†The Central Laboratory of Automation, the "Zaporozhstal'" Factory, the Dzerzhinskii Factory, the Zaporozhe Branch of TsPKB, and the Zaporozhe and Dneprodzerzhinsk Sections of the Yuvmetallurgavtomatika took part in the development and test work.

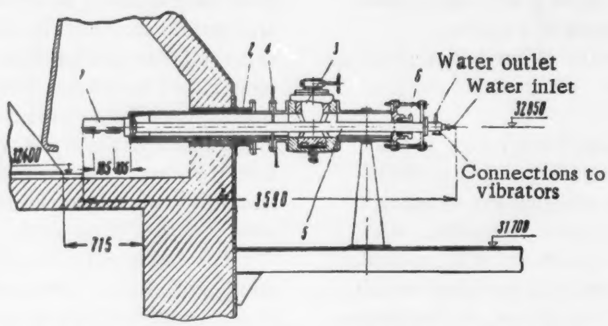


Fig. 3. Diagram showing the installation of the vibrator unit at the blast-furnace: 1) Vibrator unit; 2) guide tube; 3) stopcock; 4) Schmidt window; 5) shutoff tube; 6) stuffing box.

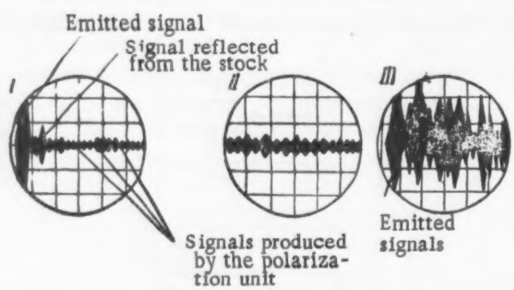


Fig. 4. Oscillograph recordings of the ultrasonic stock-level indicator: I) normal furnace operation; II) with high-voltage relay switched off (signals absent); III) during the descent of the large cone.

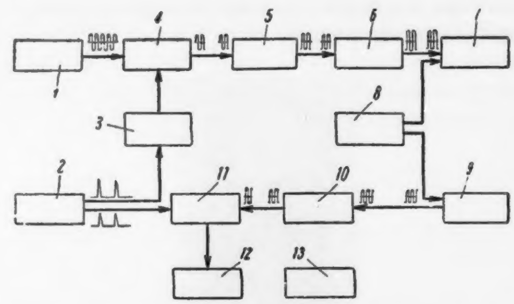


Fig. 5. Diagram of a high-capacity ultrasonic stock-level indicator: 1) master oscillator; 2) pulse train rate generator; 3) relay; 4) manipulator; 5) voltage amplifier; 6) power amplifier; 7) emitting vibrators; 8) polarization unit; 9) receiving vibrator; 10) amplifier; 11) measuring unit; 12) potentiometer; 13) supply unit.

that the emitting surface of the vibrators does not become covered with the dust which would interfere with the emission. The design of the vibrator unit is quite reliable, the unit is simple to operate, and the vibrators can be exchanged while the furnace is under full blast.

The following conclusions can be drawn from the results of the tests of this apparatus at the blast furnace: 1) A considerable increase in the power of the ultrasonic emission is necessary in order to obtain reliable signals in the range of up to 3-4 m (as measured by the ordinary stock-level indicator); 2) any further increase in the sensitivity of the receiver of the ultrasonics is pointless since the furnace in operation produces substantial interference signals.

At present, the Central Laboratory of Automation is developing a more powerful ultrasonic apparatus (up to 3 kw) in a circuit with a standard potentiometer. The diagram of this apparatus is shown in Fig. 5. The master oscillator has a frequency of 19-23 kc. The generator of the emitted signals of 10-50 cps controls the operation of the manipulator via a relay. The relay is used for the transformation of the controlling signals from the frequency generator into rectangular pulses of the duration of 0.5-1 msec. The manipulator, controlled by the relay, transmits the oscillations of ultrasonic frequency to the voltage amplifier. The ultrasonic signals, amplified in voltage and power, are transmitted to the emitting vibrator and then through the air to the blast-furnace stock. The ultrasonic signals reflected from the stock produce electric oscillations in the coil of the receiving vibrator, the oscillations are amplified and transmitted to the measuring unit. The voltage, which is proportional to the distance from the stock, is transmitted from the measuring unit to the standard potentiometer. The vibrators are magnetized by direct current from the polarization unit.

Industrial tests which are to be carried out on this apparatus in 1959 will make it possible to decide whether ultrasonic stock-level indicators can be used in blast-furnace shops. Such level indicators could also be used for the determination of the level in bins at ore-beneficiation and sintering plants.

* * *

AUTOMATIC OPERATION OF THE REVOLVING DISTRIBUTOR

N.V. Mozhaev

Central Laboratory of Automation

With the present method of charging the blast furnace by means of skips, the charge materials are not distributed uniformly in the blast-furnace top because of the formation of ridges of ore and coke on the small cone. The use of revolving distributors does not completely eliminate this nonuniformity since the foreman does not change the rotation sequence of the distributor regularly. Therefore, work has recently been started on the development of methods which would link the operation of the revolving distributor with the conditions of the peripheral gases in the blast furnace. These methods are based on the principle that a larger amount of ore is charged into the places in the furnace top where the gas temperature is higher, i.e., the gas permeability is higher, and a smaller amount in the plates of a lower gas permeability. In this way, it should be possible to equalize the temperature of the gas at the circumference in the blast-furnace top.

Such a system was developed at the Kuznetsk Metallurgical Combine. The revolving distributor was operated in such a way that an additional amount of ore was charged into the sectors with the highest temperature, and none was charged into the sectors with the lowest temperature.

The maximum and minimum temperatures were determined before the beginning of every cycle of distributor operation. The system included the possibility of operating the distributor in one position until the maximum temperature in this sector will fall below the temperature of any other sector in the blast furnace. The introduction of this system made it possible to improve the distribution of the peripheral gas flow in the blast furnace significantly and to improve the utilization of the thermal and chemical energy of the gases.

An apparatus for the control of the revolving distributor operation was introduced at the "Azovstal" "Factory too. In this system, the magnitude and the sign of deviation of the temperature of the peripheral gas from the average temperature was determined at several points. The minimum and maximum deviations were transmitted to the control system of the revolving distributor.

In 1957-1958, the Central Laboratory of Automation developed a system of revolving-distributor control, based on the temperature of the peripheral gases, for one of the blast furnaces at the Dzerzhinskii Factory. This system operates in a similar way to the system used at the Kuznetsk Metallurgical Combine. The following operating conditions are envisaged:

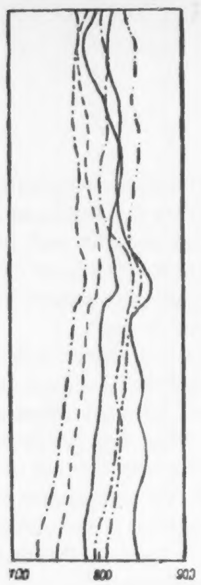
1) Two rounds are charged to the distributor in the position which corresponds to the sector with the maximum temperature of the peripheral gases, and the position which corresponds to the sector at the minimum temperature is omitted. In the remaining positions the distributor is charged in the usual way, i.e., one round for each position.

2) Two rounds are charged to the distributor in the position corresponding to the highest temperature, the remaining positions being charged as usual.

The apparatus consists of a potentiometer with an additional commutator and temperature indicator, an electronic unit for maximum and minimum temperature selection, a unit of computing relays and an additional relay panel in the circuit of the servomechanism of the rotation angle of the distributor. The temperature of the peripheral gas is measured at six points at the circumference of the furnace by means of thermocouples. The temperature readings are transmitted to the potentiometer which transmits pulses to the maximum and minimum temperature selection unit which consists of a small size electronic unit with two capacitors and two amplifiers connected directly. When the voltage changes on one capacitor, a signal is transmitted to the amplifier where it is amplified and it actuates then the maximum or minimum relay. The maximum and minimum temperature zone of the blast-furnace top are fixed by the corresponding program relay and, at the same time, the circuit of all the preceding relays is broken. The program relay actuates the servomechanism of the rotation angle of the distributor which doubles the charge of the ore to the sector of the highest temperature and omits the sector at the lowest temperature.

Tests on this system carried out at one of the blast furnaces at the Dzerzhinskii Factory showed that the nonuniformity of the gas stream was almost completely eliminated. Satisfactory results were obtained in spite of the unfavorable conditions under which the tests were carried out (the furnace was frequently incompletely charged, the temperature fluctuated and incrustrations occurred). The difference between the temperature of separate points did not exceed 50-80°C (see Fig.). In the course of operation, however, it was found that the effect of the introduction of this system on the furnace operation (doubling or omitting a round) was not adequately effective. Therefore, the Central Laboratory of Automation developed another system in which the difference between the maximum and minimum temperature was taken as the main criterion of the nonuniformity of the peripheral gas distribution. The system operates in such a way that the zone of the highest temperature is charged with an additional amount of ore, the amount being greater the greater the difference between the maximum and minimum temperatures.

The operation sequence of the revolving distribution is set up after every cycle. The thermocouples for the determination of the temperature of the gas are mounted



Temperature variations in the peripheral gas at the blast-furnace of the Dzerzhinskii Factory.

at 8 points on the circumference of the furnace. The number of rounds charged into the section of the maximum temperature is determined by a special apparatus, called a correction unit. This system will shortly be tested at the "Zaporozhstal'" Factory.

Recent types of two-program control systems for the revolving distributor make it possible to charge ore to the section of maximum temperature and coke to the sections of minimum temperature. The number of ore and coke skips will be determined according to the difference between the maximum and minimum temperatures.

The development of new methods of controlling the operation of the revolving distributor according to the temperature of the peripheral gas will most certainly help blast-furnace operators to improve the performance of blast furnaces.

* * *

AUTOMATIC RECORDING APPARATUS

V.A. Likhachev

Central Laboratory of Automation

Recently the number of measuring instruments in industrial plants has increased to such an extent that the analysis of the operation of production units has become very difficult. Hence the need for developing automatic recording instruments which can record a large number of parameters, describe technological processes on one chart and, at the same time, record them on a perforated card, or perforated or magnetic tape, etc.,has arisen. Such instruments will assist in the analysis of plant operation by means of computers and thus substantially facilitate the work of operators. The great speed at which the data can be processed by means of computing machines makes it possible to correct the technological processes in good time on the basis of data analysis. Some firms abroad have already started the mass production of various automatic recorders which are used more and more extensively in industry. Work on the development of similar recorders has been started in the USSR too. At present, there are actually three completed designs of automatic recorders in the USSR: the MAR S-300 recorder developed by the Design Office of Biophysiological Instruments), an automatic registration machine (developed by the Scientific Research Institute "NIISChETMASh") and a recording apparatus, RUMB, (developed by the Central Laboratory of Automation).

The main component in the automatic recording instruments is the converter of continuous values into discrete ones.* The type of converter determines, to a great extent, the whole system as well as the speed and the accuracy of recording. In the MARS-300 machine, an automatic potentiometer whose slider is connected with a coding disc is employed as the converter. In the recorders developed by the "NIISChETMASh" Institute and the Central Laboratory of Automation, electronic converters based on the comparison of the converted potential with the linearly varying voltage are used.

The automatic recorder RUMB is designated basically for the investigation of the blast-furnace process, but it can also be used in other industries. The characteristics of this recorder are as follows:

Number of recorded parameters	40
Speed of parameter recording, sec	0.5
Time of recording 40 parameters, sec . .	20
Accuracy of recording	±0.1%

The time interval between the recording cycles can be 1, 10, 20, 30, 40, 50, or 60 minutes.

* Discrete values are discontinuous values transmitted in the form of separate pulses.

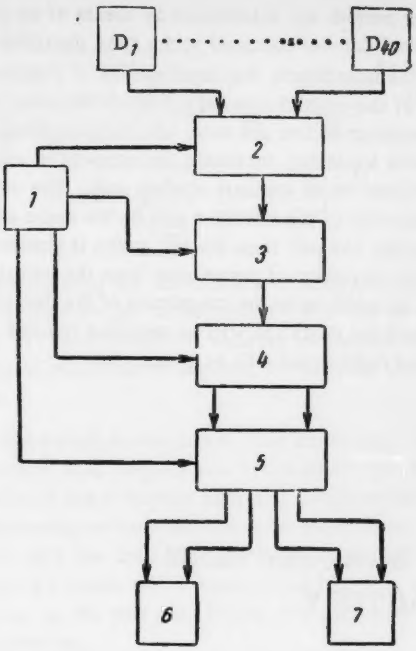


Fig. 1. Circuit of the RUMB recorder: D_1-D_{40} – data transmitters; 1) time distributor; 2) commutator; 3) converter; 4) counter; 5) decoder; 6) typing machine; 7) punching machine.

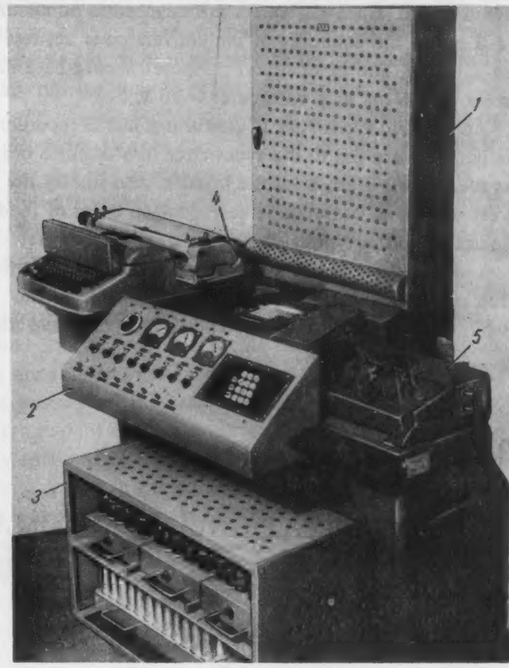


Fig. 2. RUMB recorder: 1) Electronic unit (converter, time distributor, and decoder); 2) control panel; 3) input unit; 4) typewriter; 5) punching machine.

A direct current of 0.5 ma or a constant voltage of 0-10 v serves as the input signal. The recorded parameters in the recorder are shown by means of three digit numbers of the decimal system on a typewritten sheet and by means of a standard punched card on the IP 80 puncher.

The recorder (Fig. 1) is assembled with 60 electronic valves of bantam series. The readings of the primary instruments which describe the parameters of the blast-furnace process are converted into direct current or voltage and are transmitted to the commutator. A special device (time distributor) produces a signal which switches the commutator. As soon as the commutator is set up on the first recording channel, the time distributor sends off a second signal which switches in the converter which converts the continuous signal received from the corresponding data transmitter into a series of single pulses, the number of pulses being proportional to the magnitude of the input signal.

The pulses are fed to the counter which counts them and "memorizes" the number. When the counter completes the counting of the single pulses, the time distributor sends off a signal to the decoder where the number, which the counter has memorized, is converted into a number of the familiar decimal system. From there, the number is transmitted to the printing machine and the punching machine. The recorded parameter is expressed by a three-digit number of the decimal system on the diagram of the printing machine, and at the same time the punching machine records that number on a punched card.

After the measurements have been completed, the time distributor sends out the next signal to the commutator and the second, third, and so on, up to 40th, parameter is recorded. Then, depending on the program set up by the operator, the new cycle of measuring 40 parameters is started. The time between consecutive cycles can be varied from one minute to one hour. If necessary, the operator can introduce an extra recording cycle.

A photograph of the RUMB recorder is shown in Fig. 2. The main component of the recorder is the converter for converting continuous magnitudes into discrete ones. It operates on the principle of comparison of the voltage measured with the voltage which decreases linearly. At the beginning of the measurement, a special generator producing a saw-toothed voltage is switched in. At the same time, a second generator, which produces single cadence signals of a strictly determined frequency, is switched in. The saw-toothed voltage is continuously compared with the signal being measured. While these voltages are compared, the single cadence signal generator is stopped. In this way, the number of pulses sent off by the second generator is proportional to the magnitude of the signal measured. The counter and the decoder count the pulses and convert them into decimal figures. From

0 to 1000 single pulses are sent off per parameter being measured and, since the pulses are counted to an accuracy of ± 1 pulse, the accuracy of the conversion is not less than ± 0.1%. The input signal measured should be a direct current of 0-5 ma or a voltage of 0-10 v.

An electric typewriter is usedin the RUMB recorder. The numbers are fed to the typewriter in a definite order: first the highest digit, then the middle, and finally the lowest one. The consecutive introduction order of feeding the number to the typewriter from the decoder is also effected by means of the time distributor. The commutator which switches in the data transmitters is made of the ShI-50/8 step-by-step switch. The time coding and the recording periods are determined by means of an electromechanical counter mounted in the time distributor unit.

In the near future, the development of a second version of the multichannel rapid RUMB recorder, in which semiconductors are used, will be completed. The whole apparatus, including the typewriter, can be accomodated on an ordinary writing desk. The operating characteristics of this recorder will be the same as the first version; the new recorder will make it possible to record the deviation of parameters from the normal values. In addition to the magnitude of the deviation, the sign of the deviation will be recorded too and a sound and light signal will be given.

* * *

THE MECHANIZATION AND AUTOMATION OF SOME SECTIONS OF THE CHEREPOVETS METALLURGICAL FACTORY

S.N. Bogopol'skii

Head of the Technical Department

The conveying of raw and other materials by means of belt conveyers is extensively used at the Cherepovets Factory.

Railroad cars which arrive at the Factory with coal, sinter, and iron ore concentrate are unloaded by means of rotary car tippers of 1200 ton/hour capacity. The car tipper machine is operated by one man. Soon after the introduction of the first car tipper it was found that the feeders which transfer the material unloaded onto the conveyer system were functioning very badly. It was necessary to have 4-5 men per shift to operate them and the work had to be done in an atmosphere full of dust. The components frequently broke down, the unloading operation and work at the shops was interrupted, and the idling time of the railroad cars became excessive.

On the suggestion of some of the employees at the coke and by-product plant (B.M. Provotorov, S.P. Turtygin, and M.P. Elagin), belt-type feeders were designed and installed. The feeders have been in operation for more than two years and have made it possible to free workers for other duties, to eliminate the idling time of the railroad cars, to eliminate frequent repairs as well as to utilize fully the total capacity of the unloading equipment of the works. Feeders of this type will be installed on new car tippers where materials will be transported by conveyers.

All belt conveyers are provided with an automatic block system. If any mechanism or any conveyer ceases to function, all belts and machines which convey the materials to this particular section are automatically stopped. With this arrangement, there is no pile-up which would involve a considerable expenditure of manual labor.

For a rapid stopping of individual conveyers (the total length at present is more than 30,000 m) there are emergency buttons placed at intervals of 35-50 m. It was found in practive, however, that this arrangement does not ensure a rapid enough stopping of the conveyers.

It was suggested that a cable attached to the switch-off levers of the respective sections should be laid along the conveyors. By pulling the cable, the operator could stop the conveyer immediately and because of the automatic block system, stop the whole line.

Work at the coal storage, where four men were employed per shift, was very arduous. A group of technical employees of the Works (B.M. Provotorov, S.P. Turtygin, M.N. Ionichev, G.E. Dunaev, A.P. Solov'ev and B.P. Marshkov) designed a new type of trap doors which open when the bogie of the mechanical feeder is in motion. The operator opens and closes the doors by pressing a button. This design has been accepted by the Giprokoks for the second series of coal storage and has been incorporated into the standard plant design.

A special cableway has been erected for the disposal of gangue from the coal cleaning plant. However, because of some defects in the design, the Factory could not use this cableway for about two years and had to use a locomotive, railroad cars and a bulldozer for the removal of the gangue. Four men were employed at the station, and they had to detach the small cars from the cable by hand, push them toward the bin and then push them back

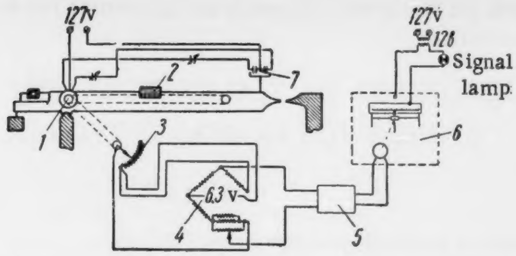


Diagram showing the automatic weighing and recording of the charge weight in the coking plant: 1) Reversible motor; 2) check weight; 3) variable resistance; 4) bridge circuit; 5) amplifier; 6) register; 7) two-pole mercury switch.

again and attach to the cable. The innovators, I.E. Men'shikov, K.S. Bobylev and V.I. Eremov, put the operation of the cableway right and modified its design by introducing several substantial improvements. At present, only one man is employed at the station and he operates the button which controls the trap door of the feed bin. In the very near future, this operation will be automated too.

Scales, operated by two men per shift, were installed for weighing the charge for the coke oven batteries. Subsequently, however, the scales were not used and the charge was measured by volume. Naturally, no adequate accuracy could be achieved. The employees of the instrumentation shop, A.I. Sokolov, A.F. Kamulin, and A.E. Denisov, by somewhat modifying the equipment of the scales, have designed an automatic system which provides not only for weighing the materials but also for recording the readings and the time of weighing (see Figure) In this way the charging operation has become more accurate and the cases of not fully charged chambers have been eliminated since one can check very accurately how much coal remains in the car after it has been emptied into the chamber. Also, since the time when the car returns to the scales is recorded it is possible to trace who is to blame for any irregularity in the charging operation.

A steel-plate conveyer for transporting sinter has been installed at the sinter plant. The rubber belt conveyer which was installed for the transportation of sinter from coolers in accordance with the original design of the plant was constantly delaying the operation of the plant and the whole Factory. The rubber belt, about 155 m long, had to be changed every month, and repaired only a few days after the change. The designers at the chief mechanic section of the Factory, B.P. Marshkov, A.P. Solov'ev, A.I. Istomin and V.N. Gridnev, designed a large-capacity conveyer made of metallic plates. The conveyer was made at our repair-and-machine shop and was installed at the sinter plant without any interruption in the operation under the supervison of the chief mechanic of the Factory, A. A. Shul'gin. The conveyer has been in continuous operation for several months. At present, we are installing another similar conveyer to replace the rubber belt conveyer, and, at the same time, we are preparing drawings for a similar conveyer 180 m or more long to be installed in the blast-furnace shop in place of the rubber belts.

On the suggestion of a group of technical workers at the blast-furnace shop, pig pushers have been installed at the end of the casting machines, and the control cabin of the turning hoist has been transferred on to the pig handler's platform who now carries out the duties of the operator.

On the suggestion of Hero of Socialist Labor, senior foreman of the blast-furnace shop, A.I. Ol'khovikov, a lined container for collecting the iron which is taken by the slag and retained in traps was installed at the slag runners of the blast furnaces. With this simple arrangement there is no more need for hard labor on the removal of solidified pig iron, and, at the same time, a substantial amount of metal is saved.

During the repair of the No. 1 blast furnace in 1959 we plan, following the example of the Magnitogorsk blast-furnace operators, to arrange for tapping the pig iron through one tap hole by installing a removable spout and an additional track for transporting pig iron. In this way, the hard work of the furnace attendants on preparing the runners will be made much easier. At the same time, we shall carry out a full automation of the blast-furnace stoves; the necessary equipment is already being supplied.

The design of a four-nozzle tun dish for the open-hearth furnace shop has been developed. Its introduction will make the work of the ladle operators and runner operators much easier. At the same time, we are preparing the mechanization of the stopper rod assembly for the steel ladles.

The change to the remote control of the pump stations and power substations will begin in 1959 and it will then be possible to release several hundred workers for other duties.

An apparatus for the automatic sampling of gas in the cross section of the blast furnace will be installed during the repair of the blast furnace and will contribute to an improvement in sampling, in the accuracy of the analysis and will make it possible to release workers who are now performing hard and dangerous duties in a gas-contaminated atmosphere. We have already received drawings of the equipment and shall start making it in the near future.

Wide discussion on mechanization and automation problems has taken place at the shops of the Factory and, in this way, it has been established in which sections the manual work should be replaced by the machine. On the basis of the suggestions which were submitted during the discussions, an integrated plan for mechanization and automation over a period of several years is being prepared.

The Factory personnel have successfully solved the problem of a rapid introduction of productive capac-

ities and now occupies one of the leading places among the establishments of the iron and steel industry in the USSR. We are confident that our personnel will cope with the task of mechanization and automation just as successfully.

* * *

THE TECHNOLOGY OF DEOXIDIZING AND ALLOYING LOW-ALLOY STEELS

B.Kh. Khan

Gas Utilization Institute, Academy of Sciences, USSR

The problems raised by I.M. Leikin, I.A. Sokolov and others* of reducing the consumption of ferroalloys and reducing the cost of low-alloy steels are very acute and important. These authors point out quite rightly that it is possible to make steel by the method which involves the introduction of hard ferroalloys into the ladle in an amount up to 22-25 kg/ton during the tapping.

Our experience on making steels of different grades by this method shows that if the steel in the open-hearth furnace is at a temperature within the range 1620-1640 °C before the tapping (this is the usual temperature of steel made in modern open-hearth furnaces with magnesite-chromite roofs), then the dissolution of hard alloys (including ferrochromium) in the liquid steel proceeds smoothly and results in a uniform composition of the steel. If the steel is completely deoxidized and alloyed in the ladle, the quality of the final steel is practically the same as the quality of the steel made by the ordinary method of deoxidation but the cost of steelmaking is reduced owing to the shorter duration of the steelmaking process and to a reduction in the consumption of ferroalloys.

In the proposed method, the following conditions must be observed:

1) The steels which are to be deoxidized and alloyed in the ladle should be made only in high-temperature open-hearth furnaces.

2) The ferroalloys must be introduced in the form of lumps not larger than 80-100 mm in cross section.

3) The addition of the ferroalloys should be started when the ladle is 1/8 to 1/5 full and completed when the ladle is 4/5 full.

4) The best way of introducing the ferroalloys is by using a bin suspended on the casting crane, and thereby letting them fall gradually and uniformly in small portions.†

5) Before it is cast, the steel in the ladle should be kept for 10-15 min and not for 5-10 min as suggested in I.A. Sokolov's article. This length of time is determined by the temperature of the steel when it is tapped. If the steel is not kept a sufficient time in the ladle a nonuniform composition of the steel in some ingots may result.

Silicomanganese and manganese steels (with up to 0.12% carbon) must be completely deoxidized in the ladle by means of silicomanganese with an addition of ferrosilicon or ferromanganese, so that the required content of silicon and manganese is obtained. To reduce the consumption of silicomanganese, one should add manganese ore in the amount of 0.8 to 1.0% during the period of slag formation or a corresponding amount of ferromanganese into the boiling bath before the tapping. When making steels which contain more than 0.12% carbon one should introduce ferromanganese and ferrosilicon, with a small addition of silicomanganese into the ladle‡.

Steels which contain chromium should also be completely deoxidized in the ladle with the use of silicomanganese, ferromanganese, and ferrosilicon while the ferrochromium should be introduced into the boiling bath 10-15 min before the tapping. Experience has shown that if the required chromium content is low (0.2% lower limit), it is desirable to add ferrochromium into the ladle while observing the conditions enumerated above. For alloying, one should use high-carbon cheap ferrochromium which has a lower melting temperature than low-carbon ferrochromium. Experience on making 14KhGS steel has shown that if the low-carbon ferrochromium (KhGO) is replaced by high-carbon ferrochromium (KhrO) when the steel is to be completely deoxidized in the ladle with silicomanganese and ferrosilicon, the cost of steel is reduced by 14-16 rubles/ton and the duration of the heat is reduced by an average of 15 min. The carbon which is introduced into the steel by the high-carbon ferrochromium is almost completely oxidized when the bath containing ferrochromium is boiling, and consequently there is no need for an additional decarbonizing of steel during the pure-boil period. The bath containing ferrochromium boils normally and this is conducive to a more rapid dissolution of ferrochromium and to the establishment of

* Metallurgist, Nos. 3 and 12, 1958. [See C.B. translation].

† Mechanized chutes (bins), by means of which the amount and rate of ferroalloy additions to the ladle can be controlled, are used for this operation abroad (USA). (Editor's note)

‡ It is desirable to add a part of ferromanganese into the furnace in order to slow down the rate of carbon loss. (Editor's note)

a more uniform compositon of the steel. Chromium loss constitutes 20-25%.**

If the steel contains nickel or copper, the method of deoxidation and alloying is determined only by the silicon, manganese, and chromium contents since nickel and copper are added to the steel at the beginning of the pure-boil period.

The investigations, which we carried out at the "Krasnyi Oktyabr'" Factory in Stalingrad, at the Izhevsk Factory and at the Stalino Metallurgical Factory, as well as the experience of other establishments, show that when the steel is completely deoxidized in the ladle the temperature of the steel made in large open-hearth furnaces remains within the same range as in the ordinary method of steelmaking. The temperature of the steel at the time of tapping depends to a large extent on the method of charging the materials into the furnace, on the correct amount of ore added during the refining period in relation to the temperature of the steel, and on the condition of the furnace.

One of the advantages of completely deoxidizing low-alloy steel in the ladle is the constant content of the main elements in the steel in every heat, and smaller variations in the composition as a result of the interaction of steel with slag in the ladle. The loss of silicon and manganese during the deoxidation of the steel in the ladle constitutes about 10% and varies from heat to heat within the limits of 1-2%. When steel is deoxidized with silicon and manganese in the furnace, their loss varies within the limits of 20-40%. In some heats, the slag contains a high amount of manganous oxide. When the steel reacts with this slag in the ladle, the manganese is formed and exceeds the required concentration limit. When the steel is completely deoxidized in the ladle the content of manganous oxide is low and the reduction to manganese does not take place.

If ferroalloys are introduced into the ladle, the loss of silicon and manganese depends on the amount of aluminum and ferrotitanium added to the steel, and on other factors.

Low-alloy steels are usually deoxidized with aluminum and ferrotitanium simultaneously. If there is a large amount of aluminum (more than 1 kg/ton), the steel is thick and a skin forms on its surface in the mold during the pouring; this results in folds which cause defects in the form of cracks at the places where the skin folds have occurred, fissures, blisters and accumulation of nonmetallic inclusions in the finished rolled product. If the steel is deoxidized with titanium, the amount of the aluminum added (including the aluminum which is in ferroalloys) should be as small as possible provided that the required density of the ingots and the properties of the final products can be ensured.

Satisfactory results obtained at the Kuznetsk Metallurgical Combine, the Alchevsk, Izhevsk and other metallurgical factories show that the complete deoxidation of steel in the ladle can be recommended for the production of all low-alloy steels.

**This is a much higher loss than for the usual method (the introduction of the ferrochromium into a deoxidized bath) and the difference is even greater if the silicochromium is added into the ladle. (Editor's note)

* * *

AN ANALYSIS OF THE PERFORMANCE OF OPEN-HEARTH FURNACES FIRED WITH AN OXYGEN-INTENSIFIED FLAME

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Makeevka Metallurgical Factory

For the analysis of the performance of the open-hearth furnaces in which oxygen was used for flame intensification at the Makeevka Metallurgical Factory, operating statistics of one furnace in a group of furnaces which were reconstructed to take double charge but in which no essential modifications of the lower structure of the furnace were made (furnaces from group I), and of one furnace from a group of large-capacity furnaces (furnaces from group II), were investigated. Data from 790 heats during which the combustion air was enriched with up to 25% oxygen were analyzed. Because of the inadequate supplies of oxygen to No. 1 open-hearth furnace shop, a higher enrichment with oxygen was very rarely encountered. However, the analysis of the results obtained indicates a further oxygen enrichment and a reduction in the duration of the heat and in fuel consumption.

The dependence of various factors which characterize the furnace operation on the total length of the charging and heating-up periods is shown in the diagram.

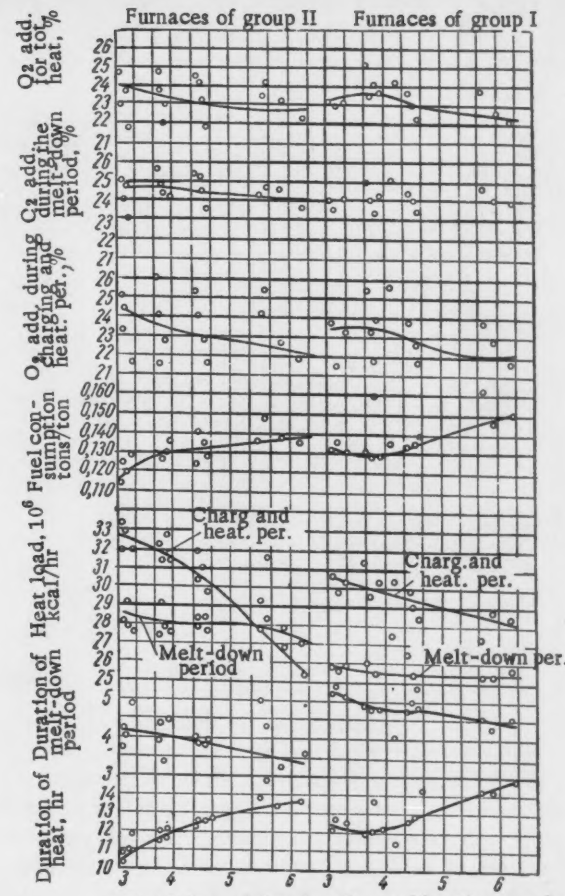
For the furnaces of group II, the reduction in the total duration of the charging and melt-down periods, with a simultaneous increase in heat load and an increase in oxygen enrichment during these periods, causes a continuous reduction in the duration of charging and heating-up periods and may lead to a sharp reduction in the duration of the total heat and in fuel consumption.

The heating capacity of the furnaces makes it possible to increase the rate of charging and heating-up. Thus, when the duration of the charging and heating-up periods was reduced from 4.5 to 3 hours, the time of melt-down period did not change. The fact that the heat load and the amount of oxygen added to the air during the melt-down period fluctuated but slightly (27.5×10^6 - 28.0×10^6 kcal/hr and 24.4 - 24.7%, respectively) indicates that an adequate amount of heat was introduced into the furnace during the charging and heating periods. Nevertheless, the optimum duration of the charging and heating periods for these furnaces was not attained. Obviously, this optimum duration is less than 3 hours and it depends not on the heating capacity of the furnaces but on the throughput capacity of the auxiliary plants and the organization of production at the shop.

The best results for the furnaces of the IInd group were obtained when the total duration of the charging and heating period was 3 hr, the heat load during these periods was 32.5×10^6 kcal/hr, and the air was enriched with up to 25% oxygen. At the same time, the heat load during the melt-down period constituted 28.5×10^6 kcal/hr and oxygen added constituted 24.5%. The heat took 10.3 hr and the fuel consumption was 112 kg/ton.

If the total duration of the charging and heating period is increased to 5 hr or more, and, at the same time, the heat load is reduced and the air is enriched with oxygen, the duration of the heat and the fuel consumption increase substantially although the duration of the melt-down period is slightly reduced owing to the high temperature of the charge. The increase in the duration of the charging and heating periods by 1.5-2.0 hr is not compensated by the reduction (0.6-0.7 hr) in the melt-down period. Therefore, the duration of the heat and the specific consumption of fuel increase. If the total duration of the charging and heating periods is more than 5 hr then the average heat load and the oxygen enrichment during these periods should not exceed 28×10^6 - 29×10^6 kcal/hr, and 22.5%, and, during the melt-down period 27.5×10^6 kcal/hr and 24.5%, respectively (see Table).

Somewhat different results were obtained for the furnaces of group I. The reduction of the total duration of the charging and heating periods down to 3 hr 40 min and the simultaneous increase in the heat load to 30×10^6 kcal/hr and oxygen enrichment to 23.5% lead to a continuous reduction in the duration of the heat and in the specific consumption of fuel. A further reduction in the total duration of these periods down to 3 hr and, at



The dependence of some characteristics of furnace operation on the total duration of the charging and melt-down periods.

the same time, an increase in the heat load to 30.5×10^6 kcal/hr and oxygen addition up to 23% does not lead to a reduction in the total duration of the heat nor in the specific consumption of fuel. This is explained by the fact that the furnaces of the Ist group have a smaller heat capacity than the furnaces of the IInd group. Therefore, when the total duration of the charging and heating periods is reduced, it is not possible to increase the heat load during these periods adequately and therefore, the charge materials are not heated up adequately and, consequently, the melt-down period is extended.

An increase in the duration of the charging and heating period to 5-5.5 hr results in an increase in the duration of the total heat and in fuel consumption, in the same way as in furnaces of the IInd group. The optimum heat loads and oxygen enrichment under certain operating conditions are given in the table.

A comparison of the furnace performance with and without the use of oxygen was made by means of a statistical analysis of the data from approximately 2000 heats (1955-1957).

TABLE

Optimum Heating Regime of the Furnaces when Oxygen is Introduced to the Flame

Total duration of charging and heating periods (hr)	Addition of oxygen to air, %		Heat load, 10^6 kcal/hr		Specific consumption of fuel, kg/ton
	charging + heating	melt-down	charging + heating	melt-down	
Furnaces of group I					
3—3,5	23,0	24,0	30,5	26,0	130
3,5—4	23,0	24,0	30,0	26,0	128
4—4,5	23,0	24,0	30,0	25,0	132
4,5—5	23,0	24,0	29,0	25,0	138
5—5,5	22,5	24,0	29,0	25,0	143
More than 5,5	22,0	24,0	28,5	25,0	148
Furnaces of group II					
3—3,5	25,0	25,0	32,0	28,0	120
3,5—4	23,5	25,0	32,0	28,0	128
4—4,5	23,0	24,5	31,0	28,0	130
4,5—5	23,0	24,5	30,0	28,0	132
5—5,5	22,5	24,5	29,0	28,0	134
More than 5,5	22,5	24,5	28,0	27,0	137

The average reduction in the duration of the heat in 1957 when oxygen was used in the furnaces of groups I and II was respectively 12% and 9%, compared with 1955 when no oxygen was used. The specific fuel consumption was reduced by approximately 20%. However, the total duration of the charging and heating periods was rather long (4.5-5.0 hr). For a shorter duration of the charging and heating period (3-4 hr), the effect will of course be substantially larger, and only then is it economic to enrich the air with 25% or more oxygen. At present, oxygen is, to a certain extent, a factor which compensates only for inefficiency in production organization at the shop and, therefore, a further increase in oxygen addition will be expedient only after a regular operation of all sections of the shop is established in accordance with the production schedule.

The duration of the campaign of large furnaces was reduced by 5.7% as compared with 1956 and this was the result of a frequent application of oxygen during the refining period of the heat. When the oxygen was used during that period, the fluctuation range of the temperature of the roof increased and, hence, the service life of the magnesite-chromite bricks was shortened. Apparently, during the refining period it is advisable to introduce oxygen into the flame by means of an injector only. By enriching the air with oxygen injected into the port, especially during the melt-down and refining period, one can stabilize the flame and make it more rigid and flat. This, in turn, will result in an increase in the service life of the roof.

On the basis of the analysis of the operation of the large-capacity open-hearth furnaces at the Makeevka Metallurgical Factory with the use of oxygen for the intensification of the flame, one can draw the following conclusions.

1) With the existing supplies of oxygen at No. 1 shop the use of oxygen in the flame of the open-hearth furnaces ensures the best results for certain combinations of the amount of oxygen introduced and the heat load of the furnace depending on the total duration of the charging and heating periods. The recommended operating conditions are given in the Table.

2) Experience on the operation of the furnaces has shown that it is expedient to use two different methods of oxygen introduction: by means of nozzles (2000 m^3/hr) during short periods of charging and heating, and by means of an injector (1200 m^3/hr) during pig-iron addition, the melt-down and refining periods.

3) During the refining period, oxygen can only be introduced by the existing method (by means of nozzles) in exceptional cases, since the introduction of oxygen in this way markedly reduces the duration of the usable period of the furnace owing to roof deterioration. It is advisable to introduce oxygen during the refining period into the port by means of an injector, since then the harmful effect of oxygen on the roof is avoided.

* * *

AN AUTOMATIC HEAT MEASURING DEVICE FOR THE STUDY OF TECHNOLOGICAL PROCESSES

Yu.B. Ostrovskii and M.Ya. Sherman

Central Laboratory of Automation

The structure of an ingot obtained on a machine for the continuous casting of steel is determined mainly by the steel crystallization process taking place in the crystallizer of the machine. If the crystallization process is carried out correctly, a fine-grain structure of the ingot is obtained, the pipe formation and the segregation are very limited, cracks are absent and the ingots have a good surface.

The steel crystallization process depends not only on the design of the crystallizer, the length and the level of the steel in the crystallizer, the speed of casting and the dimensions of the ingot cross section, but also to a

large extent on the rate of heat removal from the crystallizer.

The Central Laboratory of Automation developed a heat measuring apparatus for the automatic control of heat transfer from the crystallizer. The experimental prototype of this apparatus was installed at the continuous steel-casting machine of the Novo-Tula Metallurgical Factory. The main requirements in the operation of this instrument are determined by the operating conditions at a given plant; these requirements are: the absence of response inertia, continuous recording, and reading indication on a scale which can be easily seen from a distance.

The basic circuit of the apparatus is shown in Fig. 1. The current, which is generated by a battery of thermocouples and is proportional to the temperature difference of water at the inlet and at the outlet of the crystallizer, flows through the data transmitter (rheostat) of the water flowmeter. The voltage at the rheostat, R_G, is the function of the heat transfer from the crystallizer to the cold water.

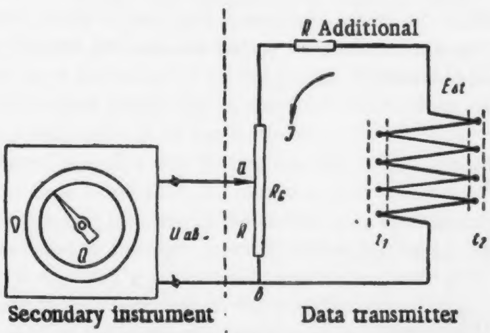


Fig. 1. Circuit of the heat-measuring apparatus.

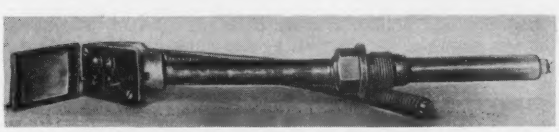


Fig. 2. Thermocouple battery.

The rate of the flow of water is measured by a flowmeter manometer with a DM6 induction indicator, and a ÉPID-07 secondary instrument which is equipped with a rheostat data transmitter. The resistance, R, determined by the position of the slider of this rheostat, is proportional to the water throughput.

The thermocouple battery consists of 10 chromel-alumel thermocouples which are arranged in such a way that their bare junctions are in direct contact with the water (Fig. 2). Owing to this design, the thermocouple battery has practically no response inertia. The "hot junctions" are placed in the pipe through which the water flows from the crystallizer, and the "cold junctions" are in a special overflow vessel with water which flows

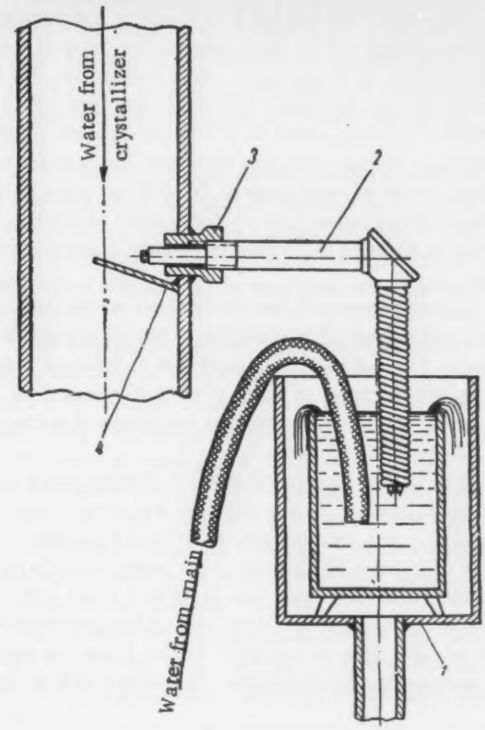


Fig. 3. Diagram showing the arrangement of the apparatus for measuring the temperature of water in the crystallizer: 1) Overflow vessel; 2) thermocouple battery; 3) boss; 4) baffle.

to the crystallizer (Fig. 3). The chromel-alumel thermocouples were chosen because of their high emf and fairly linear relationship $E=f(t)$.

An electronic potentiometer of ÉP120 type is used for the automatic recording and indication of the amount of heat transferred from the crystallizer to the cooling water. The range of the apparatus is 4 mv. The maximum water rate (80 liter/sec) for the maximum possible temperature difference of water between the inlet and outlet of the crystallizer (12.5 °C) corresponds to the highest reading on the temperature scale (1000 kcal/sec). The instrument has an easily visible scale. The recording disc makes one revolution in two hours. The experimental error of the set of instruments comprising the heat-measuring apparatus does not exceed ±1.5%.

The advantage of the apparatus designed by the Central Laboratory of Automation over the TV-16 type apparatus is the continuous recording of readings and the virtual absence of response inertia in the measurements of temperature difference. The 10-day industrial test of this apparatus on the continuous steel-casting machine showed that it is quite suitable for determining the effect of the change in water throughput in the crystallizer, in the speed of casting and in the level of the steel, and for establishing an optimum regime for heat transfer.

At present, the Central Laboratory of Automation is developing instruments for measuring low rates of water flow in small-diameter pipes; these instruments will be suitable for the automatic control of heat removal in the secondary cooling system of the continuous steel-casting machines. An apparatus has also been designed for the determination of heat losses in the cooling water of the electric-arc furnaces of the "Élektrostal'" Factory. The apparatus has a scale marked in electrical and thermal units.

In connection with the low pressure of the cooling water and because it is desirable to reduce the pressure losses in the reduced area flowmeters as much as possible, a short venturimeter in place of an orifice meter for measuring the flow of water was designed and made at the "Élektrostal'" Factory.

It should be mentioned that the pressure losses across a plate orifice are, on the average, 6-7 times larger than in a nozzle or a venturi tube, and that the pressure loss of 1 mm of water is equivalent to the power loss of a pump, airblower and other machines equal to 3 w per 1000 m^3/sec throughput. Meanwhile, in almost all flowmeters of the reduced-area type in the USSR, orifice plates for which the pressure loss constitutes on the average 50% of the pressure drop across the orifice are used. If one considers that at metallurgical works there are hundreds of flowmeters which usually operate at a pressure drop of 40-1000 mm Hg, the enormous losses of electric power become apparent.

In addition, the pressure in the pipeline is so limited that any additional loss of pressure across the orifice of the flowmeters affects the normal operation of metallurgical plants. Thus, for instance, at several blast furnaces which were modified to operate with an increased pressure in the furnace top, the air blowers which were installed earlier are operating at their maximum capacity and very frequently fall short of providing the required amount of blast to the furnace. Under these circumstances a reduction in the pressure loss in the cold-blast main and at the suction inlet of the airblower by means of replacing the orifice plates with venturi tubes or venturi nozzles may be of decisive significance.

Venturi meters, instead of orifice meters, must be more extensively used in industry. The instrument industry should organize the production of flowmeters incorporating nozzles or venturi tubes. Also, research and development work on the design of reduced-area meters which would be more economic than venturi nozzles and venturi tubes should be carried out.

* * *

A RAPID-ACTION PHOTOELECTRIC PYROMETER

M. E. Gluiberzon

One of the main parameters which determine the course of the metal-treatment process at metallurgical and machine building works is the temperature of the metal.

Disappearing-filament optical pyrometers for measuring the temperature of steel within the range of 800-2000 °C or more are particularly extensively used for industrial temperature control. In most cases, an adequate accuracy of measurements of the temperature of the surface of a metal heated to white heat is obtained by OPPIR pyrometers, which are widely used in industry and in which the observers eye plays the part of the comparison instrument. However, these "subjective" pyrometers have several serious shortcomings, of which the most important is the fact that the temperature cannot be continuously measured and recorded, particularly in processes of short duration.

In 1951, the Central Laboratory of Automation developed the first Soviet model of an "objective" photoelectric pyrometer, type FÉP-3, which incorporates a STsV-51 photoelement whose spectral response in the region of the red spectrum is very similar to the spectral response of the average human eye, owing to this fact it was possible, by combining the photoelement with a red filter of KS-3 glass, to make an instrument which determines the brightness temperature of a body in a light of the effective wavelength of 0.65 microns.

The majority of brightness pyrometers of other types and the standard methods and instruments for optical pyrometry are also designed for operation in a light of 0.65 microns effective wavelength. Owing to this fact, it is possible to calibrate and test photoelectric pyrometers by means of methods and instruments which are accepted and widely used in optical pyrometry.

The following is a simplified description of the operation of the FÉP-3 pyrometer. Two beams of light, one from the radiation source (a hot body whose temperature is to be determined) and the other from a special lamp in the anode circuit of a dc amplifier, fall on two openings of a light modulator mounted in front of a photoelement (Fig. 1). Both light beams are modulated in opposite phases by means of a shutter vibrating at a frequency of 50 cps.

When these two light beams are equal, the photoelement current is almost free from the variable component and the current of the lamp remains constant. When the temperature of the hot body and its luminescence changes, the variable component in the photoelement current increases, its phase is determined by the sign of the difference between the values of the currents of the hot body and the lamp, and its amplitude is determined by the magnitude of this difference. The variable component is amplified by an ac amplifier and is transmitted to a phase-sensitive detector.

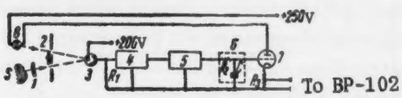


Fig. 1. The basic circuit of an FÉP-3 photoelectric pyrometer: S) Radiation source; 1) objective; 2) light modulator; 3) photoelement; 4) ac amplifier; 5) phase-sensitive detector; 6) integrating filter; 7) dc amplifier; 8) feedback lamp.

The dc voltage received by the phase-sensitive detector is smoothed by an integrating filter and is fed to the control grid of the dc amplifier valve which has a filament lamp in its anode circuit. The circuit is designed in such a way that an increase in the intensity of the light beam from the radiation source causes a corresponding increase in the current and, consequently, an increase in the light intensity of the filament lamp.

In this way, a pronounced negative feedback with regard to the magnitude of the variable measured is effected in the pyrometer, and the photoelement in fact plays the part of a zero indicator. Thus, if the amplifying power of the amplifier is sufficiently high, the accuracy of the measurements is almost independent of the degree of amplification, the sensitivity of the photoelement and the parameters of other elements of the system, but depends only on the stability of the conversion of the current into the light beam by the filament lamp.

The optical system of the pyrometer ensures a constant solid angle in the image space and, therefore, the light beam from the hot body to the photoelement is always proportional to the brightness of the hot body (provided that the pyrometer is correctly set up and focused).

It follows from the aforesaid that the current of the filament lamp (called the feedback lamp in FÉP photoelectric pyrometers) is determined uniquely by the light beam from the light source and, hence, it constitutes a measure of the brightness temperature of the source.

The voltage drop across the standard resistance R_s (Fig. 1) included in the incandescent lamp circuit is measured by a rapid-action BP-102 electronic potentiometer whose scale is calibrated in °C.

The responsiveness of the apparatus, i.e., the interval between the appearance of the hot body before the objective of the pyrometer and the moment when the hand and the pen of the recording potentiometer are set on the scale mark which corresponds to the temperature of the body is 2.5-3 sec.

In this way, the measurement and the recording of the temperature of a hot body situated within the field of vision of the instrument can be obtained within 3 sec.

The increase in the speed of rolling on modern high-speed rolling mills and the extensive application of the high-frequency heating of steel require quick-response optical pyrometers.

In 1957, the Central Laboratory of Automation developed a photoelectric pyrometer with 0.8-1.0 sec response lag. The principle of operation and the design of the main compents of this instrument are similar to the FÉP-3 pyrometer. The only modifications were those made in the electronic circuit of the sighting head and the power unit of the pyrometer as well as in the design of the circuit of the amplifier of the quick-response BP-102 potentiometer. In addition, the design of several elements of this instrument was modified to increase its reliability in operation and to facilitate the calibration of the pyrometer.

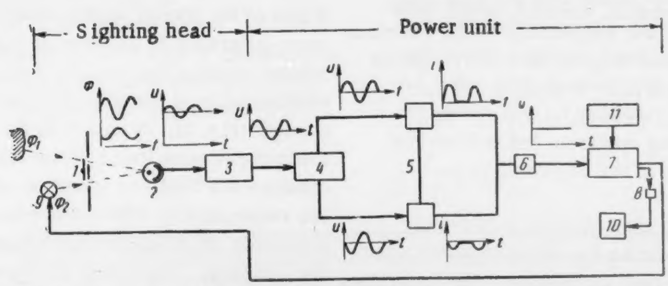


Fig. 2. Diagram of the modified photoelectric pyrometer: 1) Light modulator; 2) photoelement; 3) primary amplifier; 4) phase-inverting amplifier; 5) phase-sensitive detector; 6) integrating capacitor; 7) dc amplifier; 8) output filter; 9) feedback lamp; 10) rapid-response potentiometer; 11) power unit.

The circuit of this photoelectric pyrometer is shown in Fig. 2. The main difference between the electronic circuit of this pyrometer and the circuit of the FÉP-3 pyrometer is the use of a highly effective phase-sensitive detector in the form of a differential phase bridge

To increase the stability of the operation of the circuit, a feedback lamp is included in the cathode circuit of the lamp of the dc amplifier which thus operates as a cathode follower. With this arrangement, a reliable operation of the instrument is ensured since any accidental burning-through of the feedback lamp filament is prevented.

In addition, some parts of the optical system of the pyrometer have been modified and standardized so that the instrument can be used in more diverse positions.

A temperature-range switch has been designed so that is is now possible to make pyrometers which can be used for two ranges of temperature, and, hence, the over-all range of temperatures which can be measured by the pyrometer has been extended to 4,500 °C.

In this connection, a method of extrapolating the scale of the FÉP pyrometers to the range of temperatures above 2000 °C has been developed.

The increase in the response speed of the BP-102 electronic potentiometer has been attained by lowering the gear ratio of the balancing electric motor D-32. Owing to the introduction of a specially designed ÉU-5071 amplifier to replace the ÉU-42 amplifier, a reliable operation of the equalizing circuit of the potentiometer at high speeds of operation has been ensured. A differentiation filter has been installed at the input terminals of the bridge to increase the dynamic stability of the system.

At present, the Central Laboratory of Automation is preparing the production of experimental specimens of the modernized rapid-response photoelectric pyrometers for 1959-1960.

* * *

THE ADOPTION OF THE VALVE-CHANGE INTEGRAL RELAY FOR USE AT SMALL-CAPACITY OPEN-HEARTH FURNACES

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As is known, the valve-change integral relay operates satisfactorily with large and medium open-hearth furnaces. The relay automatically determines the time interval between the valve changes depending on the amount of heat accumulated in the checkers in the course of each period of the steelmaking process.

For small capacity furnaces, however, which have a shorter charging period, the temperature of the checkers after the tapping of the heat remains relatively high for some time and the integral relay continues to effect the valve changes at more frequent intervals. This interferes with the charging operation and reduces the rate of heating the charge at the beginning of the charging period.

In order to extend the time interval between the automatic valve changes during the charging period when the checkers are still at a high temperature, the integrating relay is switched to the motor time relay by means of a special switch (Fig. 1). The switch is changed from the position "I" into the positions 4, 6, 8, etc. At the same time, the slider of variable resistance R_2 - R_{13} is switched out of the circuit of the integral relay, and only a part of the R_2 - R_{13} resistances is switched into the circuit of the motor relay, depending on the required time interval between valve changes. The handle of the switch is mounted in the lower corner of the potentiometer cover and is joined to the shaft of the switch which is mounted on the internal wall of the revolving frame of the potentiometer which measures the temperature difference at the checker top. The handle has a pointer which slides over the scale made up of graduations corresponding to the time intervals between the valve changes (Fig. 2). By means of the switch which converts the integral relay into a motor relay, it is possible to continue the charging operation while the valve changes are automatically effected at required time intervals depending on the operating conditions which obtain during the charging. The switch is simple and compact, and allows the time intervals between valve changes to be set at 4, 6, 8, 10, and 15 mins.

After the charging period is completed, the relay is set up again for normal operation by means of resetting the switch in the position " I".

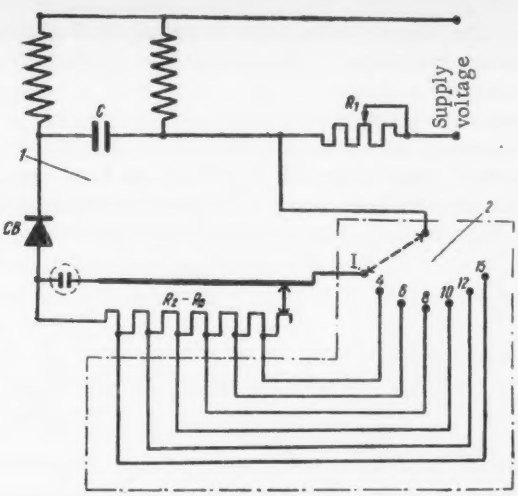


Fig. 1. Circuit of the integral relay and of the switch which converts the integral relay into the motor relay: 1) Integral relay; 2) switch; 3) on-off switch of the integral relay; 4), 6), 8), 10), 12), and 15) positions of the slider of the motor relay on the scale corresponding to the time intervals between the valve changes.

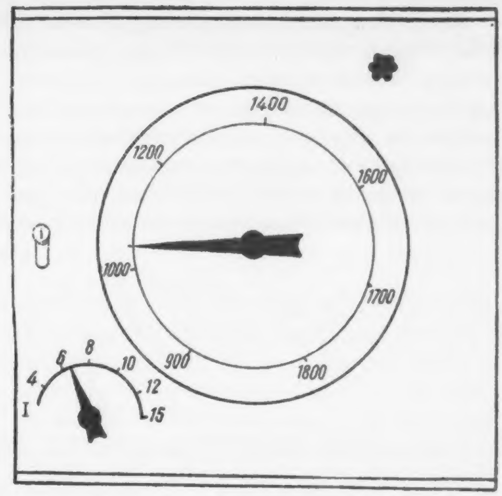


Fig. 2. Arrangement of the switch handle on the potentiometer.

* * *

OXYGEN LANCE FOR BREAKING DOWN STEEL BULKS

P.N. Vasenkov

Kuznetsk Metallurgical Combine

In the scrap preparation plant, one frequently encounters massive steel bulks ("skulls", rolls from rolling mills, etc.) which have to be broken down by blasting. At the Kuznetsk Metallurgical Combine an oxygen lance (shown diagrammatically in the Figure) is used for making blast holes.

The working tube (6) should pass freely through the annular gap between the tubes (4) and (5) so that it can easily be replaced when it is burnt away.

The lance is ignited in the following way. A metal plug (approx. 500 mm long) made of wire is inserted into the working tube. The end of the tube with the plug is inserted into the coke hearth and the oxygen valve is opened. Under the action of the oxygen, the coke begins to burn intensely and in a few seconds the tube and the wire ignite. Without any increase in oxygen input the lance is transferred to the steel bulk in which a blast hole is to be pierced; the hot end of the tube is pressed firmly against the place where the hole is to be pierced and the oxygen valve is gradually opened more widely. When the tube with the plug burns, the particles of molten steel under the action of the oxygen stream bombard the steel bulk which begins to burn at the place of the contact with the tube. The valve is then opened fully to allow the maximum flow of oxygen.

Fig. Oxygen lance for piercing blast holes: 1) 20 mm diameter tube; 2) connecting piece; 3) valve; 4) 6 mm diameter tube; 5) 20 mm diameter tube; 6) working tube.

The lance can be used for piercing the holes with the use of oxygen at 3-10 atmos pressure. If the pressure is less than 3 atmos the hole becomes plugged with slag since the oxygen stream does not have sufficient energy to remove the slag. It is not recommended to increase the pressure above 10 atmos since the spattering slag may become a source of danger to the workers. The best results are obtained with oxygen at 6-7 atmos pressure.

The rate of piercing depends not only on the oxygen pressure but also on the diameter and the length of the burning tube. A tube 8 m long and 16 mm o.d., when used with oxygen at 5 atmos pressure, burns through in 3.5 min, and in that time a hole 400 mm deep can be made. A tube 12 mm o.d., 8 mm i.d. and 8 m long, when operated at the same oxygen pressure, burns through in 3 min and in that time a hole 450 mm deep can be made.

* * *

THE FOURTH MEETING OF THE STEELMAKING SECTION OF THE PERMANENT COMMISSION FOR THE IRON AND STEEL INDUSTRY OF THE COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE

M.A. Pertsev and D.A. Smolyarenko

In January, 1959, the Fourth Meeting of the Steelmaking Section of the Permanent Commission for the Iron and Steel Industry of the member countries of the Council for Mutual Economic Assistance was concluded in Honnigsdorf (East Germany). Specialists on steelmaking from Bulgaria, Hungary, East Germany, Poland, Rumania, the USSR, and Czechoslovakia took part in the proceedings of the meeting.

At the conference, reports by specialists from communist-block countries on the development of the steelmaking industry and on methods of increasing the steel output in 1959-1965 and the output of special alloy steels to provide for the requirements of the chemical machinery and chemical plants which are being constructed were read and discussed, and proposals with regard to steel scrap economy were worked out.

The main trend in the rebuilding of old, and the erection of new, open-hearth shops was the establishment of high output shops with provision for casting the steel into molds on bogies and with special sections for the preparation of molds and the stripping of ingots. Because of the specific conditions of raw materials (high phosphorus content, lean iron ores, brown coal) in some countries, the active mixer was fairly extensively used and the open-hearth furnaces were fired preferentially with producer gas.

At several establishments of the member countries of the Council for Mutual Economic Assistance, the steel shops were modernized and, at some factories, the open-hearth furnaces were modified to take double charge (the Brandenburg Factory in Eastern Germany).

The leader of the Bulgarian Delegation, I. Boyadzhiev, reported that steel output in the Bulgarian Republic in 1958 amounted to 211,000 tons, and for 1965 it is envisaged to increase the output to 855,000 tons. On the advice of the USSR, the capacity of the steel pouring ladle will be increased by means of applying welded construction, a mixer will be installed, the weighing of the liquid pig iron before it is poured into the open-hearth furnace will be introduced, vaporization cooling will be applied and waste-heat boilers will be built at all operating furnaces. The meeting recommended an improvement in the utilization of the furnaces by means of increasing the average weight of the charge, reducing the length of the periods of furnace fettling and furnace charging.

The Meeting asked the Hungarian, Soviet and Czechoslovak metallurgists to supply Bulgarian steel manufacturers with technical details on the preparation of the charge for melting (a method which has been introduced and has justified itself) and on methods of hot repairs to the open-hearth furnaces.

The leader of the steelmaking section and representative of the Hungarian People's Republic, I. Balshai, pointed out that in order to utilize the available capacities of Hungarian open-hearth furnaces, in particular at the "Dunai-Vashmyu" Factory, it is necessary to increase the throughput capacity of the rolling mills. Development work on increasing the speed of charging, increasing the heat load, improving the durability of the lining, increasing the temperature of the steel during tapping and reducing defective production is being carried out at other iron and steel works in the Hungarian Republic. The metallurgists are working to reduce the steel losses which are incurred during the bottom-pouring of steel. In 1958, Hungary produced 1,623,000 tons of steel, and it is planned to increase the output to 2,162,000 tons of steel in 1965.

The steel melters of East Germany are at present solving the problems of enlarging their furnaces, applying oxygen, using highly heat-resistant materials, employing

preliminary removal of silicon and sulfur from pig iron, and improving their methods of heating the hot top of ingots in order to increase the yield of useful material. The vacuum treatment of steel and induction mixing of the bath are being introduced into electric steelmaking production in East Germany. The block lining of electric furnaces is extensively used at steel works. By means of technical improvements it is planned to increase the steel output in Eastern Germany to 5,090,000 tons of steel by 1965 as compared with 3,477,000 tons produced in 1958.

The participants at the meeting visited the Brandenburg, Freital, and Honnigsdorf Iron and Steel Factory in East Germany.

The large steel factory in Brandenburg has 11 modern open-hearth furnaces which are operated on the scrap-ore process with the use of 48-50% liquid pig iron containing up to 1% Si, 0.45% P, and 0.06% S. The Factory produces all grades of steel, from technically pure mild iron to alloy steels. The furnaces of more than 100 ton capacity are used preferentially for the production of mild steel of up to 0.22% C content. Special attention is paid to the preparation of scrap at the Works. The installation of a triple-action baling press with a capacity of 80 tons compressive force at the final compression for producing 1200-1400 kg bundles, $630 \times 800 \times 1500$ mm, has been completed. The output capacity of the press constitutes 25 bundles per hour.

To increase the quality of steel and steel alloys at the "8th May, 1945, Factory" (in the town of Freital), it is planned to start production of steel in vacuum furnaces and to introduce the vacuum treatment of liquid steel in the ladle and during the pouring.

The steel melters in East Germany are continuously improving the utilization of equipment and, in this, they are assisted by the adoption of Soviet practices for furnace repairs. Thus, the adoption of Soviet practice at the Brandenburg Factory has made it possible to reduce the idling periods of 140-160 ton furnaces during full repairs (including the heating-up period) from 12 to 6 days. The time for lining the walls of electric furnaces has been cut from 17 to 7 hours.

The output of steel in Poland in 1958 was 5,630,000 tons, and the planned output for 1965 is 9,000,000 tons. The Lenin Huta (Iron and Steel Factory) in Krakow has been provided with modern equipment, and scientific and research institutes for ferrous metallurgy and refractories have been established. The technology of the production of magnesite-chromite roof bricks of apparent porosity up to 20% is being developed, methods of mechanizing the slag removal from slag pockets are being worked out; the injection of compressed air into open-hearth furnace ports and the modernization of some steelmaking shops with a view to eliminating bottlenecks in casting bays and charge yards are planned.

In 1959-1965, in the Rumanian People's Republic, the change to pouring the steel on bogies will be effected, a further introduction of basic roofs for open-hearth furnaces and an improvement in pig iron quality by means of reducing the content of silicon and sulfur will be carried out. The establishment of large metallurgical centers in Hunedoar was a big achievement for the People's Regime. In the steelmaking shop of this Factory, the capacity of the open-hearth furnaces has been increased, a new furnace has been built and 20-ton electric arc furnaces for the production of high alloy steel have been installed.

The Factory makes extensive use of the practice of the Kuznetsk Metallurgical Combine on sintering the furnace bottom; tests on the use of forsterite bricks in the upper rows of the checkers of the air regenerators, as well as on the use of silicochromite and high-alumina bricks of more than 42% Al_2O_3 and porosity of 18%, are being continued. New 185-ton open-hearth furnaces incorporating the automatic control of temperature and pressure in the furnace have been put into operation. Methods for the coupled or selective control of heat load and fuel supply by means of computing machines are being developed and introduced.

The planned output of steel in 1965 in the Rumanian People's Republic is 2,500,000 tons (the steel output in 1958 was 915,000 tons).

Czechoslovak metallurgists are making a significant contribution to the development of steelmaking production. They produced 5,510,000 tons of steel in 1958, and now plan to increase the output to 10,000,000 tons in 1965. At the same time, more than 75% of the total steel output will be produced in furnaces with basic roofs, the repair periods will be reduced, the heat load will be increased, the automatic control of temperature will be introduced, the use of oxygen will be extended, oxygen plants will be built and 400-ton open-hearth furnaces will be put into operation. The injection of compressed air into the flame in the open-hearth furnace is applied extensively.

To increase the yield of useful product, the hot top of the ingots is oxygen heated by means of a thermite mixture consisting of 14% Al, 35% FeSi (75%), 25.5% SiMn and 25.5% lime; thermite consumption is 1.15 kg/ton. When the mixture burns in the oxygen stream, the slag and the upper layers of the steel are heated up and, because of a slow heat loss, the ingot acquires a sound structure with only small pipe so that the hot-top crop of the ingot can be reduced to 8-9% (compared with 17% previously).

As a result of discussions of the reports, the section advised, in view of the increased production of Bessemer steel with the use of oxygen, that the quality of production of Bessemer steel should be regularly checked and that the economics of the converter process should be investigated.

In accordance with the resolution of the Tenth Session of the Council for Mutual Economic Assistance, the Steelmaking Section considered the problem of the production of special steels and bimetals for use in the

chemical industry. Taking into account the preferential use of stainless, acid-resistant, scale-resistant and heat-resistant steels and bimetals in the chemical industry, the Section recommended the production of the following steel groups and steel grades.

Group 1. Stainless and acid-resistant steels: 1Kh13, 2Kh13, Kh17N2, 9Kh18, OKh13, Kh14, Kh17, and others.

Group 2. Scale-resistant and heat-resistant steels: Chromiumsilicon, chromiumnickel, chromiummolybdenumvanadium, Kh6S, Kh23N18, 1Kh18N9T, 15Kh1M1F 25Kh2M1F, (E1723), 1Kh21N5T, (EI811) and OKh21N6F2T.

On the basis of the proposal presented by the USSR, acting as the coordinator, the distribution of scrap in the member countries of the Council for Mutual Economic Assistance for 1959-1965 was worked out. It was recommended that the supplies of scrap for the Danube countries should be improved by means of cooperation in the work on lifting sunken boats in the Danube and the Black Sea, and that the economics of these operations should be considered. The recommendations passed at the Meeting envisaged the carrying out of a number of practical measures with a view to extensive specialization and cooperation in the field of steelmaking and these measures should be conducive to a successful fulfillment of the development plans for the national economy of the member countries of the Council for Mutual Economic Assistance in the current Seven-Year Period.

The cooperation of the steel melters of the Socialist block countries in 1959 assists in the adoption of advanced techniques, in raising the technical level of production and in a rapid increase in steel output. The meeting of the Steelmaking Section of the Permanent Commission for the Iron and Steel Industry of the member countries of the Council for Mutual Economic Assistance took place in a friendly atmosphere, with complete unanimity and mutual understanding.

M. A. PERTSEV

Leader of the Soviet Group of the Steel Section of the Permanent Commission for the Iron and Steel Industry of the Council for Mutual Economic Assistance.

D. A. SMOLYARENKO

Member of the Steel Section of the Permanent Commission for the Iron and Steel Industry of the Council for Mutual Economic Assistance.

* * *

PHOTOELECTRIC INSTRUMENTS FOR CHECKING THE DIMENSIONS OF ROLLED SECTIONS

G.Kh. Zarezankov and R.V. Lyambakh

Central Laboratory of Automation

The continuous increase in the speed of rolling and higher requirements made by consumers with regard to the properties of rolled steel brought about the development of special instruments for automatic contactless measurements and control of the dimensions of steel sections in the course of rolling.

Photoelectric instruments for automatic and contactless measurements of the dimensions of cold and hot rolled sections were developed at the Central Laboratory of Automation. First of all, the problem of measuring the width of a hot plate and the diameter of a wire was solved; various photoelectric instruments based on three principles of measurements: photocomparison, phototracking, and time pulse (photo-pulse), were designed and commercially tested.

The most effective method for measuring the dimensions of rolled sections under industrial conditions was found to be based on the time-pulse principle of measurements consisting of the following. When, for instance, the diameter of a wire is measured, the wire is illuminated by an auxiliary light source and the shadow of the wire is projected onto a screen by means of an optical system. To measure the diameter of the wire, one has only to measure the size of the shadow on the screen. A mechanical device for scanning the shadow image, and a photoelement are located behind the screen. The action of the scanner is similar to the movement of a shutter with an opening, through which the light from just a small section of the image on the screen can pass to the photoelement. The photoelement is illuminated when the slit moves over the bright part of the screen and is darkened when the opening moves over the shadow. If the opening moves at a constant speed, the darkening period of the photoelement is proportional to the size of the shadow, i.e., the diameter of the wire.

A special electronic circuit, incorporating semiconductor triodes, produces a voltage which is proportional to the duration of the darkening pulse of the photoelement and, hence, from the reading of the voltmeter pointer or an automatic compensator one can determine the diameter of the wire.

If the high speed (of the order of about 10-30 m/sec) and high temperature (up to 1200 °C) of the measured section necessitate a contactless measurement which is effected by measuring not the section itself but its image on the screen, then, because of the movement and the vibrations of the section in the plane perpendicular to the direction of rolling, special arrangements must be made in order to ensure the required accuracy of measurements.

When there are lateral movements of the section along the light beam one can, by using an optical system with a long focal length (a teleobjective), achieve the stabilization of the image dimensions in the place where the image is scanned. The displacements of the section across the light beam do not change the size of the image but merely change its position in the location of scanning. Since the speed of scanning the image within the field of vision is constant, the duration of the dark period of the photoelement is independent of the position of the image.

The movements of the section in the direction across the light beam affect the duration of the dark-period pulses of the photoelement and, hence, cause an error proportional to the ratio of the velocities of the lateral movement and of scanning. To reduce this error, fairly high speed of scanning was selected so that the time of scanning the whole field of vision was 0.01 sec.

In addition, the direction of scanning is reversed every 0.01 sec and this is equivalent to reducing the above error by a factor of approximately ten.

The above principle of measuring the dimensions of an object from its shadow by means of the time length of the photoelement signal determines a number of industrially important features of photoelectronic instruments, based on this principle. The main features of these instruments are:

a) no contact with the object measured, so that the dimensions of cold or hot rolled sections moving at high speed can be measured;

b) an adequate accuracy of measurements even when the section measured is subjected to vibrations and displacements within the field of vision of the instrument, the accuracy being ensured by the use of a teleobjective and linear high-speed scanning of the object;

c) the absence of error in the readings when there are considerable variations in the transparency of the medium caused by steam, scale, dust, and flame, since the dimension of the rolled section is determined not by the intensity of the shadow produced by the section but by the time length of the dark-period pulse of the photoelements;

d) the instrument is stable in operation and its initial adjustment is simple owing to the pulse-relay

system of the operation of the electronic circuit and the use of semiconductor triodes and diodes in the circuit.

Up to now, on the basis of the time-pulse principle, the Central Laboratory of Automation has developed the first experimental specimens of three types of the instrument which are now used commercially at metallurgical works.

Figure 1 shows the apparatus, installed at the wire mill of the Magnitogorsk Metallurgical Combine, for measuring the diameter and ovalness of the wire. This apparatus measures two mutually perpendicular dimensions of hot-rolled wire simultaneously by means of two independent optical systems (measuring heads) whose readings are given by a two-hand dial with a common scale. The instrument shows, for instance, the horizontal and vertical dimensions of the cross section of the wire simultaneously, while the distance between the two hands indicates the ovalness of the wire. The required position of the optical systems of the instrument can be set up remotely by means of a rotation mechanism and a special handle (marked "inclination") mounted on the dimension indicator, so that one can check the shape of the whole cross section of the wire and detect any defects, e.g., deviations from circular cross section, slivers, scratches, etc.

By changing the direction of the measurement by means of rotating the optical systems around the wire, one can determine the dimensions of the cross section in different directions from the position of the two hands on the dial, and the type of the defect from the way in which the position of the hands changes in the course of this rotation.

By rotating the optical systems from one extreme position to another ($\pm 50°$) and by observing the continuous change in the readings indicated by the hands, one determines the ovalness of the wire from the maximum distance between the hands. If, in the course of rotation, the hand which measures the "sides" of the wire moves rapidly in the plus direction and rapidly returns, then the wire has slivers and the rolling process involves overfilled passes. If, however, the hand which measures the "sides" (the width of the wire) moves rapidly in the plus or minus direction during the rotation and then moves smoothly (no rapid comeback as in the case of the slivers), the cross section of the wire has a shear deformation and this indicates a faulty adjustment of the mill rolls.

The scale of the instrument has divisions of 0.05 mm and is designed for measuring wire of 4.5-8.5 mm diameter. The experimental error in the determination is of the order of 1-1.5% of the magnitude measured.

The fluctuation in the voltage of the 220 v supply circuit is $\pm 20\%$; electric interference from the operation of welding equipment and the movement of cranes has practically no effect on the accuracy of the measurements. When in use, the apparatus has to be adjusted only on special occasions. The above accuracy in measurements is obtained if the lateral vibrations of the wire remain within the limiting sleeves with pobedit draw plates of 12 mm diameter.

For normal operation, without readjustments, the total change in the amplitude of measuring signals may vary by a factor of 2-3

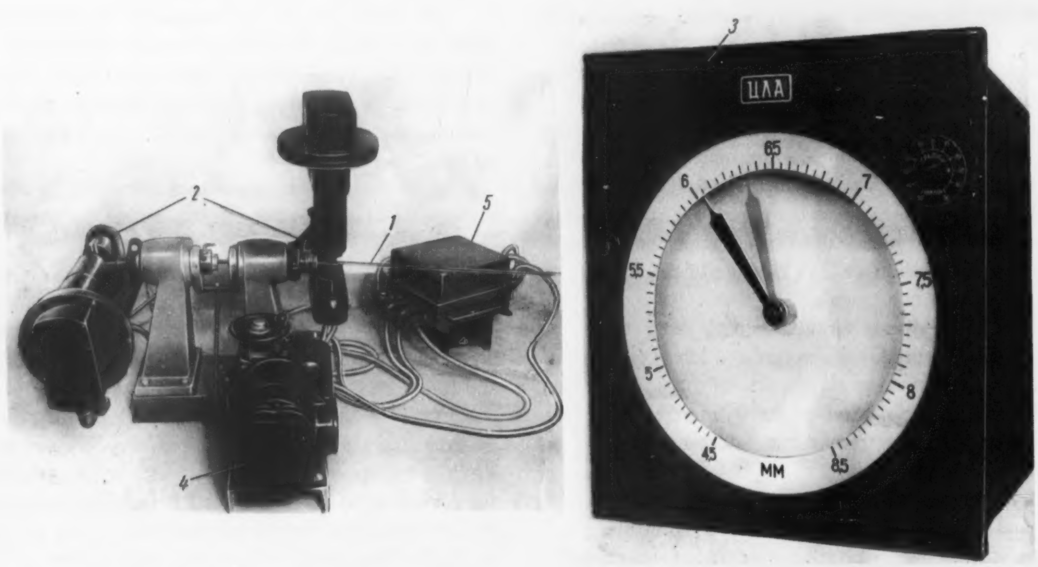


Fig. 1. Apparatus for measuring the diameter and ovalness of the wire: 1) Wire being measured; 2) measuring heads; 3) two-hand dial for dimension readings; 4) reversing mechanism; 5) power pack.

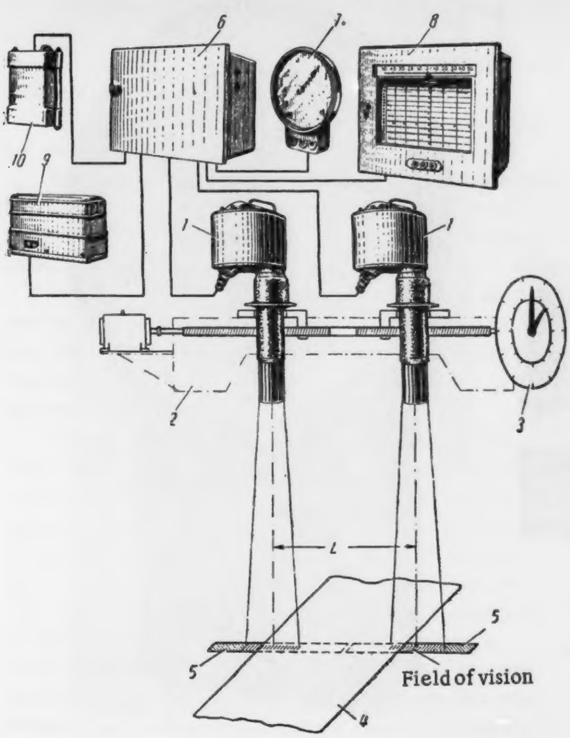


Fig. 2. Apparatus for measuring the width of a strip: 1) Photoelectronic measuring heads; 2) head movement mechanism; 3) indicator of the rating of the strip being rolled; 4) strip; 5) illuminator; 6) power pack and amplifier of the scanning system of the indicator; 7) and 8) indicator and recorder of the deviations from the nominal dimensions of the strip; 9) voltage stabilizer; 10) transformer.

It was found that during the initial stages of rolling the hot wire rod may sometimes be enveloped by the flame which does not however interfere with the measurements.

A second version of the apparatus (Fig. 2) based on the time-pulse principle was designed for measuring the width of the sheet during hot rolling at the thin-sheet mill of the "Zaporozhstal'" Factory.

The apparatus for measuring the width of the strip has two photoelectronic measuring heads mounted on a special mechanism for setting the distance between the heads at a height of 2 m above the strip. Before the rolling operation is started the measuring heads are set by means of the adjusting mechanism at a distance L (shown by the indicator) equal to the nominal width of the strip. Two illuminators with daylight lamps are placed underneath the strip and illuminate the two edges of the strip.

The field of vision of each head is approximately 200 mm and this is the limiting range of the lateral displacement of the strip during the rolling process. The measuring heads with corresponding electronic circuit determine the voltages which define the position of the strip edges in the field of vision of each head. The total voltage, which is proportional to the deviation of the strip width from the nominal width, is passed to the scanning systems of the indicating and recording instruments. The position of the hands of the indicator and recorder indicates the magnitude of the deviation from the nominal width of the strip (700-1500 mm) within the limits of ±50 mm; one division is equivalent to 2mm; the speed of the instrument is 33 mm/sec. The dynamic error of the instrument is negligible for practical purposes.

When the supply voltage varies within ± 20% and the signal amplitude changes by a factor of 2 because of the fluctuation in the brightness of the illuminator, in the transparency of the medium and in dust deposition on the optical parts, the error is still insignificant and the instrument is stable in operation even with electric interferences in the mill.

An apparatus (Fig. 3) based on a similar principle of operation has been designed for measuring wire of 1-7 mm diameter to an accuracy of 5 microns, which is necessary when the size of cold-rolled wire is checked. Since these wires have regular circular cross sections after they have been ground, their diameter is measured in one direction only. The apparatus has three ranges of measurements: 1-3 mm, 3-5 mm, and 5-7 mm.

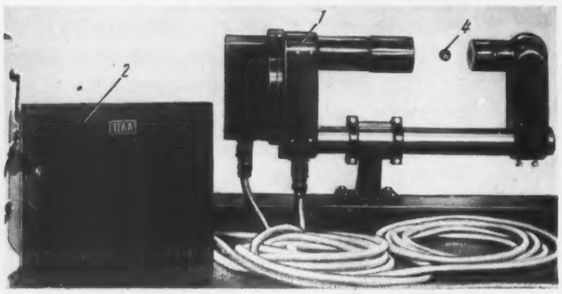
The change from one range to another is effected by turning a special handle on the dimension indicator without any readjustment of the instrument. The apparatus is adjusted only once and it needs to be readjusted only in special cases.

The error of the scale in each range does not exceed ± 5 microns and it can be corrected by resetting the hand on the dial when one nominal size is measured for a long period of time. The standard deviation of the readings of the instrument in four hours of continuous operation is less than 3 microns.

The displacement of 1-7 mm wire along the light beam within the limits of 4 mm causes an error of not more than 5 microns. A vertical displacement within the limits of 1 mm causes an error of 6 microns. fluctuations of ±10% in the supply voltage do not affect the readings.

The linearity of the scale of these photoelectronic instruments and the linearity of the temperature expansion of the rolled sections make it possible to adjust the scales of these instruments to indicate the cold-condition dimensions of the hot-rolled section by taking into account the expansion of the steel at an average temperature.

The experimental specimens of the instruments for measuring the diameter of wire and the width of strip, based on the photo-pulse method of measurement with



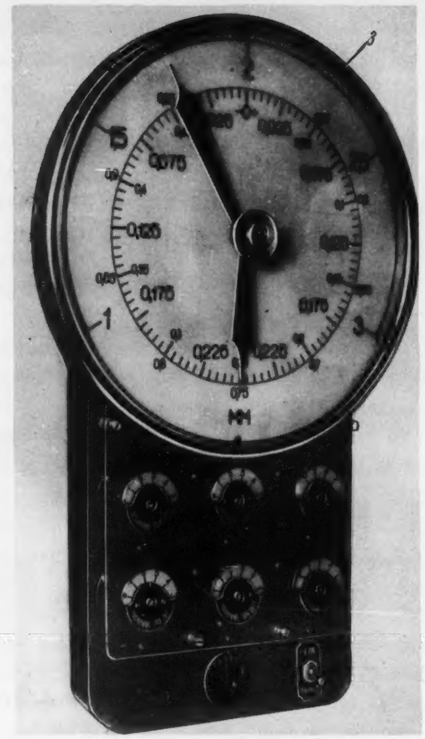


Fig. 3. Apparatus for measuring the diameter of the wire: 1) Measuring head; 2) power pack and amplifier; 3) dimension indicator; 4) wire being measured.

the use of the illumination of the section measured, can be used for measuring hot as well as cold materials.

A change in the intensity of illumination by a factor of 2 and variations in the supply voltage which occur frequently under industrial conditions do not affect the accuracy of the readings of these instruments.

Commercial operation of these experimental photoelectronic instruments showed that these indicators considerably simplify and facilitate the inspection of the width of strip and of the diameter of wire in the course of the rolling process, assist in increasing the output of the first-grade product and make the adjustment of continuous rolling mills much easier.

Automatic contactless indicators of the dimensions of steel sections in the course of the rolling process provide the prerequisites for the realization of an automatic system of rolling-mill adjustment to negative tolerances and for the automatic control of rolling mills.

At present, the Central Laboratory of Automation is carrying out development work with view to improving these instruments, i.e., in proving the responsiveness, the accuracy of measurements and the reliability, and reducing their size.

* * *

THE DETERMINATION AND CONTROL OF THE OPTIMUM FUEL-TO-AIR RATIO BY THE METHOD OF SEEKING THE TEMPERATURE MAXIMUM

A. L. Malyi

A very important factor in the control of a direct fired heating unit (furnace, boiler, etc.) is to ensure the supply to the combustion zone of a definite amount of air (oxygen) necessary for the most efficient combustion of the fuel charged to the unit.

Usually (except when injection burners are used) this problem is solved by using a system of controlling the fuel-to-air ratio. However, a constant fuel-to-air ratio does not ensure the optimum excess air even when the fuel consumption remains constant.

This is most frequently caused by the following factors:

1) a change in the composition, calorific value and moisture content of the fuel;

2) variations in the air losses (not measured) in the air duct or leakage of air into the combustion zone;

3) deviations in the values of humidity, temperature, density, viscosity and other properties of fuel and air from the values assumed in the design of the measuring instruments;

4) chemical reactions taking place in some industrial plants. Attempts to stabilize the conditions of fuel combustion result in a considerable complexity of the control system and, as a rule, do not ensure a satisfactory result.

Several attempt have been made to correct the operation of the regulators of the fuel-to-air ratio according to the composition of the flue gases, mainly according to the oxygen content of these gases. This method of control is rather ineffective, cumbersome and, in some cases, it is difficult to apply and is not very reliable in operation owing to: a) the difficulty in selecting such a point in the furnace where the gas composition would always be the same as the average composition in the whole cross section of the flue and where no air leakage would take place; b) inadequacy of the determination of O_2 alone and the necessity for determining CO and CO_2 as well; c) the dust content in the gas; d) the lag and inertia of the system of gas analysis.

In this article, we shall discuss the possibility and expediency of using an entirely new method of controlling the combustion by means of the automatic or manual selection of such an air input rate at which the maximum temperature of the flame or of a furnace element whose temperature represents an effective measure of the flame temperature is attained.

This selection (or so-called "search") is effected automatically by means of an extreme-condition regulator. However, a very good result can be obtained even by the manual determination of the optimum air input by the method of selecting an extreme * value of temperature.

To test the possibility of the application of an extreme-condition regulator for the control of the combustion in the furnace, an experimental determination of the relationship between the temperature of the flame and the input of the air was carried out at one of the reheating furnaces of the "Serp i molot" Factory. The furnace was fired with fuel oil. The temperature of the flame was measured by means of directing the telescope of a radiation pyrometer through the doors of the furnace onto the flame.

The temperature was measured at three points along the flame and it was found that if an extreme temperature at given conditions is observed in one cross section, the extreme temperature is achieved over the whole length of the flame†.

Since the extreme temperature of the surface heated by the flame corresponds to the extreme temperature of the flame, then if one selects the air rate which corresponds to the extreme temperature in the zone of the flame operation, the temperature, T_s, of this surface will also have the extreme value even if the flame is not within the field of vision of the telescope. From this point of view, the telescope of the radiation pyrometer can be replaced by a thermocouple. While, however, in the measurements of the "visible" temperature T_f of the flame one can ignore the time lag and the sluggishness of changes, their effect will be noticeable when the temperature of the surface is measured through the flame (T_{fs} or T_s). The sluggishness will be especially large if the temperature is measured by means of thermocouples.

All these assumptions have been confirmed experimentally.

At the Magnitogorsk Metallurgical Combine, a radiation pyrometer was directed through the second door of the soaking zone of the continuous furnace of the medium-plate rolling mill onto the flame on the background of the open door in the opposite wall. In spite of the small angle of vision of the pyrometer ($d/l = 1/25$), a part of the hot wall was within the field of vision but occupied not more than 10% of the field. Therefore, the temperature measured could not be considered to be the temperature of the flame but it was very near to that temperature. The dependence of this temperature, T_f, on the amount of air supplied to the burners is shown in Fig. 1 (curve 1). The same dependence obtained under the same conditions except that the pyrometer was facing a closed heated-up door is shown in Fig. 1 (curve 2).‡ It is seen that the extreme (maximum) air input increased by not more than 1.0% and this can be explained by a reduction in air leakage after the door was shut, as well as by inaccuracies in the curves near the maximum. The change in the absolute values of the extreme temperature is of no importance in this method. This fact confirms the conclusion that for the determination of the temperature maximum by varying the air input, there is no need to measure the temperature of the flame, T_f, and that one may measure the temperature of the flame and of the hot surface, T_{fs}. The magnitude of the time lag is then much less than 3 sec and the time constant does not exceed 10 sec.

When these curves were plotted, it became apparent that the extreme conditions, according to the

* Limiting (maximum or minimum). In this case, maximum.

†The experimental work was carried out by Eng. A.G. Butkovskii.

‡The experiments at the Magnitogorsk Metallurgical Combine were carried out by V.P. Strakhov (TsNIIKA), V.Ya. Gilod MMC Heat Laboratory) and the personnel of the Instrumentation and Automation Dept. of the MMC

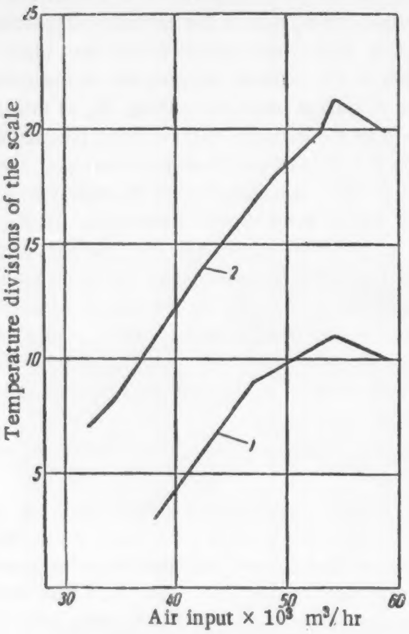


Fig. 1. Temperature T_f as a function of the rate of air input: 1) Measurements with the pyrometer facing the open door ($Q_{extr.\,air}$ = 2320 m³/hr, α_{extr} = 0.967; 2) measurements with the pyrometer facing the surface of the closed door ($Q_{air\ extr}$ = 2340 m³/hr, α_{extr} = 0.975).

readings of the air flowmeter set up at the furnace, were attained at the input rate of 5020-5040 m³/hr, while the theroretical amount of air necessary for combustion was 2440 m³/hr. It was found that the orifice flowmeters, set up at the air line, were calculated for different operating conditions. This fact was confirmed during the operation of the same furnace when the extreme conditions were determined in the lower welding zone fired with fuel oil. The extreme temperature was obtained at the air rate of 12,600 m³/hr as measured by the flowmeter whereas the theoretical air input was equal to 6,500 m³/hr. After the recalculation of the orifices it was found that the air input corresponding to the extreme temperature ($Q_{extr.\,air}$ for the soaking zone of the furnace was equal to 2320 m³/hr, while the theoretical amount was 2440 m³/hr; for the welding zone the air input was 5450 m³/hr while the theoretical amount was 6500 m³/hr; α (ratio air supplied:theoretical air required for combustion) for the soaking zone was equal to 0.95 and for the welding zone 0.84 (owing to air leakage from outside).

Air to the continuous furnaces of the light section mills of the Magnitogorsk Metallurgical Combine is supplied by an air blower through the recuperators; since the recuperators are not quite tight some air losses occur in them. The graphs for the extreme temperatures for various fuels were determined (Fig. 2) and, from them, V.Ya. Gilod, an engineer in the Heat Laboratory of the Combine, compiled tables by means of which one can determine the necessary air rate for various types of fuel.

It is seen from Fig. 2a that the search for the extreme temperature was started when an excess air was used. As the excess air decreased, the temperature of the flame and of the door surface, on which the radiation pyrometer was directed, increased. When the air rate decreased, the surface of the door was slowly cooled down and, therefore, the return to the extreme temperature conditions caused an increase in temperature again. If, however, the temperature of the body at which the radiation pyrometer is directed through the flame, changes faster than the rate of determining the corresponding points on the temperature vs. air input curve, then the maximum is "lost", as it happened in the case represented in

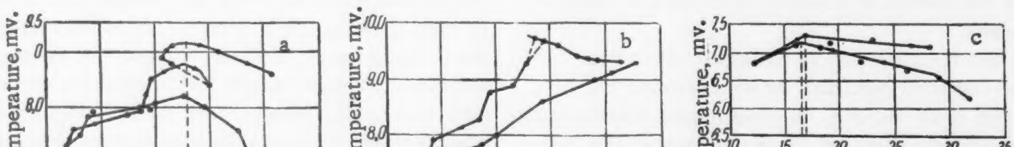


Fig. 2. The dependence T_f and T_{fs} on the amount of air supplied: a) Fuel: mixed coke-oven and blast-furnace gas (H.V. = 2400 kcal/m³); Q_{gas} = 5700 m³/hr; heat load 13.7 × 10⁶ kcal/hr; $Q_{theor.\ air}$ = 12.5 × 10³ m³/hr; $Q_{extr.air}$ = 22.7 x 10³ m³/hr; b) fuel: mixed coke-oven and blast-furnace gas (H.V. = 2400 kcal/m³) and coke-oven gas (H.V. = 4000 kcal/m³); $Q_{mix.gas}$ = 2700 m³/hr; $Q_{coke\text{-}ov.gas}$ = 2100-2300 m³/hr; heat load = 14.9-15 × 10 kcal/hr, $Q_{theor.\ air}$ = 14.6 × 10³ m³/hr; $Q_{extr.air}$ = 24-24.5 × 10³ m³/hr; c) fuel: mixed coke-oven and blast-furnace gas (H.V. = 2400 kcal/m³) and fuel oil (H.V. = 9600 kcal/kg); heat load 13.6 × 10⁶ kcal/hr; Q_{gas} = 2100 m³/hr; Q_{oil} = 830 kg/hr; $Q_{theor.air}$ = 12 × 10³ m³/hr; $Q_{extr.air}$ = 16.4 - 16.5 × 10³ m³/hr.

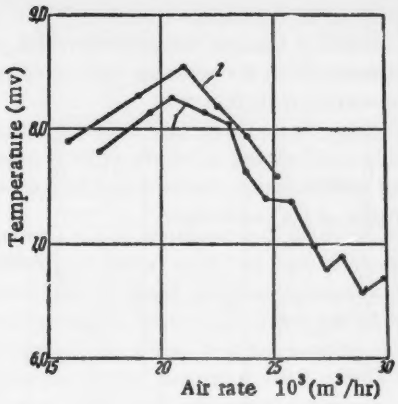


Fig. 3. The dependence of T_{fs} on the air input. Fuel: coke-oven and blast-furnace gas mixture (H. V. = 2400 kcal/ m^3) and fuel oil (H.V. = 9600 kcal/kg):1) Q_{gas} = 3000 m^3/hr, Q_{oil} = 1100 kg/hr; heat load = 17.8 × 10^5 kcal/hr; $Q_{theor.air}$ = 17.3 × 10^3 m^3/hr; $Q_{extr.air}$ = 20.5 × 10^3 m^3/ hr; 2) Q_{gas} = 4650 m^3/hr, Q_{oil} = 700 - 750 kg/hr; heat load = 17.9 - 18.3 × 10^6 kcal/hr; $Q_{theor.air}$ = 17.3 - 1.79 × 10^3 m^3/hr; $Q_{extr.air}$ = 21.0 × 10^3 m^3/ hr.

Fig. 2,b (curve 2), while curve 1 reveals a distinct maximum. Air losses constitute 10,000 m^3/ hr, similar to the case represented in Fig. 2,a. These losses, however, are not constant and, according to the curves shown in Fig. 2,c, decreases to 4,500 m^3/ hr.

The air losses at the furnaces of the light-section mill at the Magnitogorsk Metallurgical Combine (Fig. 3) were very small; they nevertheless constituted 15% of the air supplied to the furnace. In Fig. 3 the displacement of the maximum is especially clearly shown when one type of fuel is replaced by another, although owing to a greater density of fuel-oil flames the opposite door was hardly visible.

During temperature measurements of the flame from fuel oil, from gas-oil mixture and in some cases, of gas alone by means of the pyrometer, temperature fluctuations at the frequency of 0.1-0.2 cps were observed and some scatter of the pyrometer readings took place. Therefore, it is recommended that 3-4 points near the maximum should be determined. In such cases, the extreme-condition regulator should be equipped with a filter.

A very interesting subject for extreme-condition control is the tunnel furnace into which the fuel is fed to the annealing zone. Air to this zone is supplied in part directly through the tunnel and, in part, (in several types of these furnaces) it is drawn off by a fan or an injector before it enters the annealing zone and is then supplied to the burners. Because of the varying air losses, local variations in the resistance to air flow, and other causes, it is not possible to measure the amount of air entering the combustion zone. Because of the poor mixing of gases, the control system of the air input, based on the gas analysis, becomes cumbersome and hardly effective. At the same time, the automatic control of temperature and the maintenance of the required temperature conditions for annealing are not possible without an accurate control of the air input. For the control of combustion (i.e., of gas and air input), the radiation pyrometer is directed onto one of the bricks in the lining through a thin layer of the flame. Under these conditions, one measures T_{fs} but the effect of the surface temperature is much higher in this case and the maximum is, in practice, found from the temperature of the brick surface. This explains the time lag of the order of 7-10 sec and the increase in the time constant to 30-40 sec.

The fact that the values for the time lag and the time constant are still very small is the result of the high temperature of the flame and the low thermal conductivity of the brick, which results in its surface reacting so quickly to the changes in the temperature of the gases.

At one of the furnaces we installed the extreme-condition regulator which could determine the temperature maximum for a given gas consumption to an accuracy of 3 °C (for a nominal value of the temperature of 1580 °C). This experiment** showed that for a certain adjustment of the distribution of the injected air to the burners, the temperature at points 28, 27, and 26 differs by 0-10 °C from the maximum temperature attainable.

It is obvious that the extreme-condition regulator provides the solution to the problem of air input control to the firing (combustion) zone of the tunnel furnace; it is, however, essential that the air is correctly distributed to the burners, and that the furnace is operating smoothly.

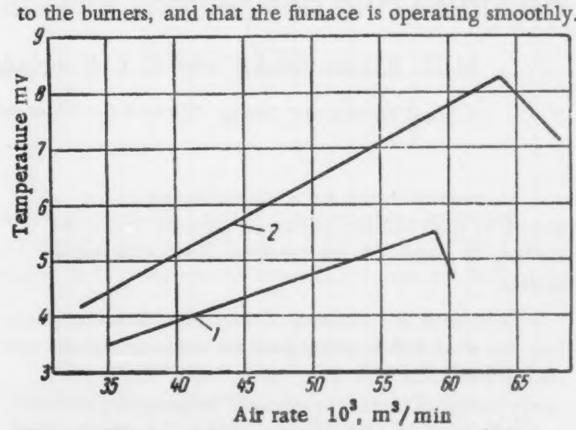


Fig. 4. The dependence of T_s on the amount of air supplied to the reheating soaking pits of the blooming mill: 1) Fuel: blast-furnace gas (H.V. 850 kcal/ m^3; $Q_{blast\text{-}fur.gas}$ = 60 m^3/ min); 2) fuel: blast-furnace gas (H.V. 850 kcal/ m^3, $Q_{blast\text{-}fur.gas}$ = 40 m^3/ min) and coke-oven gas (H.V. = 4000 kcal/m^3, $Q_{coke\text{-}oven\ gas}$ = 2.7 m^3/min).

**The work on testing the regulator and determining its characteristics was carried out by V.R. Ksendzovskii (TsPKB), E.E. Volodin and I.L. Sharol (TsNIIKA).

The reliability of the determination of the extreme temperature when the flame is not visible or when it is difficult to direct the pyrometer on to the flame, was tested at the reheating regenerative soaking pits at the blooming mill of the Magnitogorsk Metallurgical Combine. The telescope of the radiation pyrometer was directed on an ingot at a distance of 1/3 of its height from the pit bottom. Measurements were made from the side of the waste gas outlet. The curve (Fig. 4) exhibits a maximum and this provides a proof that it is not at all necessary to know T_f or T_{fs} in order to determine or control the air input rate which corresponds to the limiting temperature it is sufficient to have a surface, heated by the gases, available for temperature measurements. Before the extreme temperature regulator is installed, one must, however, determine the static and dynamic relationships in every individual case.

We have spoken earlier about the "search" for an air quantity which would correspond to the maximum temperature. It is clear, however, that the search for this maximum can be made not only by varying the air input at a certain fuel consumption, but also by varying the fuel consumption at a certain air input. If the air supply is limited, for instance by the capacity of the air blowing equipment, it is obviously better to carry out the search by means of varying the fuel rate.

The method of extreme temperature search provides means for determining the optimum fuel-to-air ratio without measuring their flow rate.

At existing plants which have ratio regulators it is now possible to check and adjust the ratio by means of a simple and most accurate method based on the very characteristics of the combustion.

Since, however, the conditions of the air supply, the heating value of fuel, and other factors may fluctuate, it is more advantageous to use extreme-temperature regulators for the automatic control of combustion, particularly because the tube layout and the equipment are more simple, there is no need for a fixed length of the straight sections of the tube and, most important, one can attain an accuracy in maintaining the required ratio to a degree unattainable by other methods.

Investigations on the use of the extreme-temperature control of combustion should be carried out on most diverse heating units, including open-hearth furnaces and boilers.

The method of extreme-temperature search should also be used during the adjustment of the thermal operation of furnaces.

* * *

THE AUTOMATIC CONTROL OF THE THERMAL REGIME OF REHEATING CONTINUOUS AND CHAMBER FURNACES

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An essential factor for an improvement in the quality of steel heating and for an increase in the efficiency of furnaces is the automation of temperature control.

At present, the majority of continuous furnaces at iron and steel factories are provided with equipment for the automatic control of temperature, and in the newly designed furnaces automatic temperature control is an integral part of the furnace design.

The standard designs of automatic control for continuous furnaces embody the following control systems:

a) the control of the temperature of the working space in each heating zone;

b) the control of the ratio of fuel to air for each heating zone *;

c) the control of the pressure in the working space of the furnace;

d) the control of the pressure and heating value of the gas at gas-fired furnaces; and of the pressure and temperature of fuel oil for oil-fired furnaces.

Figure 1 shows the basic diagram of the automatic control system for a three-zone continuous furnace fired with oil.

The temperature control unit consists of a sensing element (a thermocouple or a radiation pyrometer), an ÉPP-120 type electronic potentiometer and an IR-130 control attachment.

To attain the necessary temperature of the steel for rolling, it is important to ensure that the steel is at the predetermined temperature when it is delivered from the furnace. The technique of the continuous control of the temperature of the steel in the heating space of the furnace has so far not been mastered, and

*Recently, gas furnaces with injection burners which require no special equipment for regulating the fuel-to-air ratio have been extensively introduced.

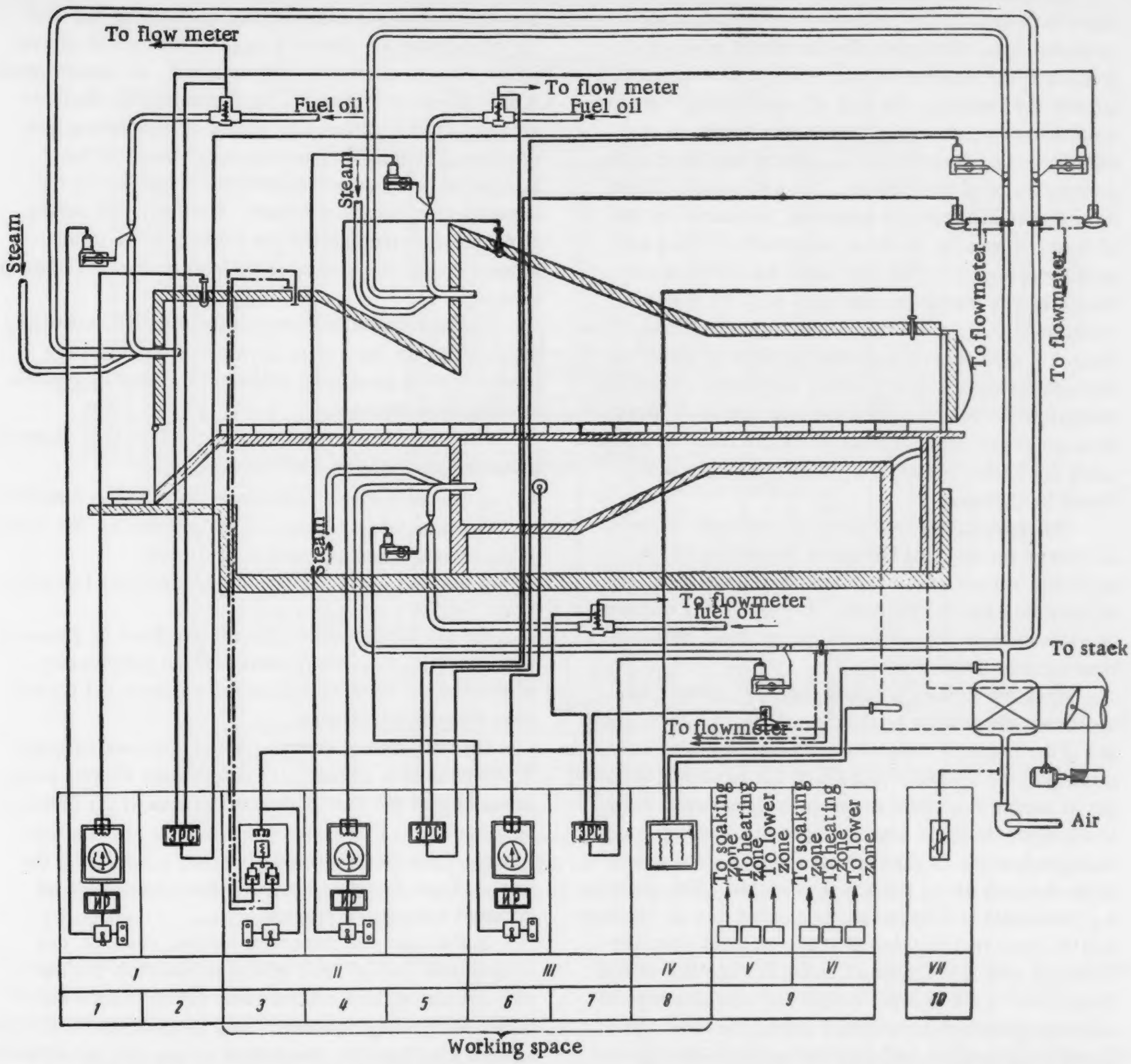

Fig. 1. Diagram showing a system of temperature measurements and automatic control of a continuous reheating furnace: I) Soaking zone; II) heating zone; III) lower zone; IV) furnace end, waste gases and hot air; V) air for each zone; VI) fuel for each zone; VII) cold air: 1), 4), 6), 8) temperature; 2) 5) 7) fuel-to-air ratio; 3), 10) pressure; 9) flow rate.

the temperature of the steel is evaluated from the temperature of the heating space. The temperature in the working chamber of the furnace, preset by the operator, can be maintained by the regulator to an accuracy of ± 10 °C.

A proper heating of the steel, however, depends on the constant throughput of the mill and the furnaces. If the throughput changes, one must adjust the temperature in the separate heating zones of the furnace in relation to the throughput of the mill, i.e., one must relate the operation of the mill with that of the furnace. Such an interdependence is not provided for in the existing systems of automatic control. Therefore, if the rate of rolling is changed, the furnace operator has to change the setting of the temperature regulator and this has a negative effect on the heating of the steel.

The combustion of fuel with a preset excess air is ensured by the regulators of the fuel-to-air ratio. The actual excess air, however, in the working space of the furnace may be quite different from the preset value because of the air leakages into the furnace on the one hand and the air losses on the other. In addition, the effectiveness of the fuel-to-air ratio regulators at several furnaces is impaired by an inadequate capacity of the air blowers, especially when the heat duty of the furnace and the air losses are high.

One should also point out that the ÉRS-67 electric regulator of the fuel-to-air ratio does not ensure a good control during transitional processes.

Changes in the input of fuel and air to the furnace cause variations in the hydraulic regime of furnace operation, i.e., changes in the amount of released products of combustion and the leakage of some extra air into the furnace. The task of maintaining hydraulic conditions at which leakages and losses would be at a minimum is carried out by the pressure regulator in the working space of the furnace. The air leakage affects the economics of furnace operation, increases the loss of metal in burning, causes a nonuniform heating and partial cooling of billets. To limit the leakages and the losses to a minimum, one must vary the pressure maintained under the furnace arch if the heat load of the furnace is changed. In gas-fired furnaces in which the flame is directed onto the metal, one should reduce the pressure if the heat load is increased; and in oil-fired furnaces or gas-fired furnaces where the flame is directed along the heated metal, the pressure under the arch should be increased.

The quantitative changes in air leakages or losses, and hence the required change in the setting of the regulator, depend on the furnace design, the dynamics of the flame and its direction. At present, the furnace operator changes the setting of the regulator manually from time to time.

When the furnace delivery doors are opened, an additional disturbance in the thermal regime takes place and if the regulator carries out the corresponding adjustments, the hydraulic regime of the furnace is impaired. Let us assume that there is a negative pressure at floor level; if the delivery doors are opened, additional air leakages into the furnace take place, i.e., the pressure under the arch of the furnace is increased. The controlling instrument will open and, as a result, the air leakages will increase still further. If at the moment when the doors are opened, the pressure in the furnace is positive, then a drop in the pressure occurs and consequently the controlling instrument is closed and hence losses increase even further. Locating the pressure-sensing element at zero-pressure level, for instance at the level of the furnace floor, will give somewhat better results with the existing control systems.

At several furnaces the operation of the pressure regulator is also affected by any defects in the electric control instruments.

In spite of all these shortcomings, the automatic control system for the thermal regime considerably improved the heating of the steel and resulted in a reduction in fuel consumption by 4-10% at various factories, a decrease in metal losses, an improvement in working conditions and the release of some operating personnel for other duties.

Nevertheless, the existing systems of automatic control for the thermal regime of continuous reheating furnaces require further improvements. If the operating conditions of the furnace change, the setting of the regulator should be changed automatically. Thus, for instance, if the rate of rolling changes, the setting of the temperature regulators should be changed too, and for this purpose an objective signal which would characterize the rate of rolling must be found. An improvement in the operation of the unit for controlling the fuel-to-air ratio can be achieved by means of introducing into the control system a correcting signal based on the analysis of the combustion products or sent out by the extreme-temperature regulator. Similarly, the setting of the pressure regulator in the working space of the furnace should be changed if the heat load of the furnace changes.

The realization of these relationships will constitute the first step on the way to developing self-adjusting systems for the automatic control of the heating regime of continuous furnaces.

The automatic control system of batch-type furnaces includes the control of the following:

a) the temperature in separate zones of the furnaces;

b) the fuel-to-air ratio. If fuel oil is used, the control of the fuel-to-atomizer ratio is envisaged;

c) the pressure in the working space of the furnace.

For oil-fired furnaces, the oil fuel must be prepared appropriately, i.e., the pressure and the temperature of the fuel oil must be maintained constant and the oil must be sufficiently pure.

For temperature control systems, the working space of the furnace is divided into temperature control zones depending on the size of the surface area of the actual heating floor. This division is necessary because the bottom of the furnace is not uniformly loaded with the steel and one therefore needs different fuel inputs on different sides of the furnace.

In the course of furnace operation, however, one temperature control zone affects another; this is quite understandable since all the zones of the furnace are inside one heating chamber. As a result of this interaction, a piece may become overheated on one side and underheated on the other. The furnace operator must then increase the preset heat input on one regulator and reduce it on the other. To reduce this affect, it is advisable to select another arrangement of the control zones by installing the thermocouples in the roof along the center of the furnace and including two (or four, i.e., two on each side of the furnace) opposite burners in one control zone.

Figure 2 shows a diagram of an automatic control system for the heating regime of an oil-fired chamber furnace. The furnace is divided into four temperature control zones; each of the zones comprises the combustion space for the fuel oil from two or three adjoining burners. Platinorhodium-platinum thermocouples, for measuring the temperature, are mounted in the middle of the roof and operate in conjunction with an ÉPP-120, IR-130 and a servomechanism. The thermocouple is mounted in a porcelain sheath without any additional protective covering. This method of mounting the ther-

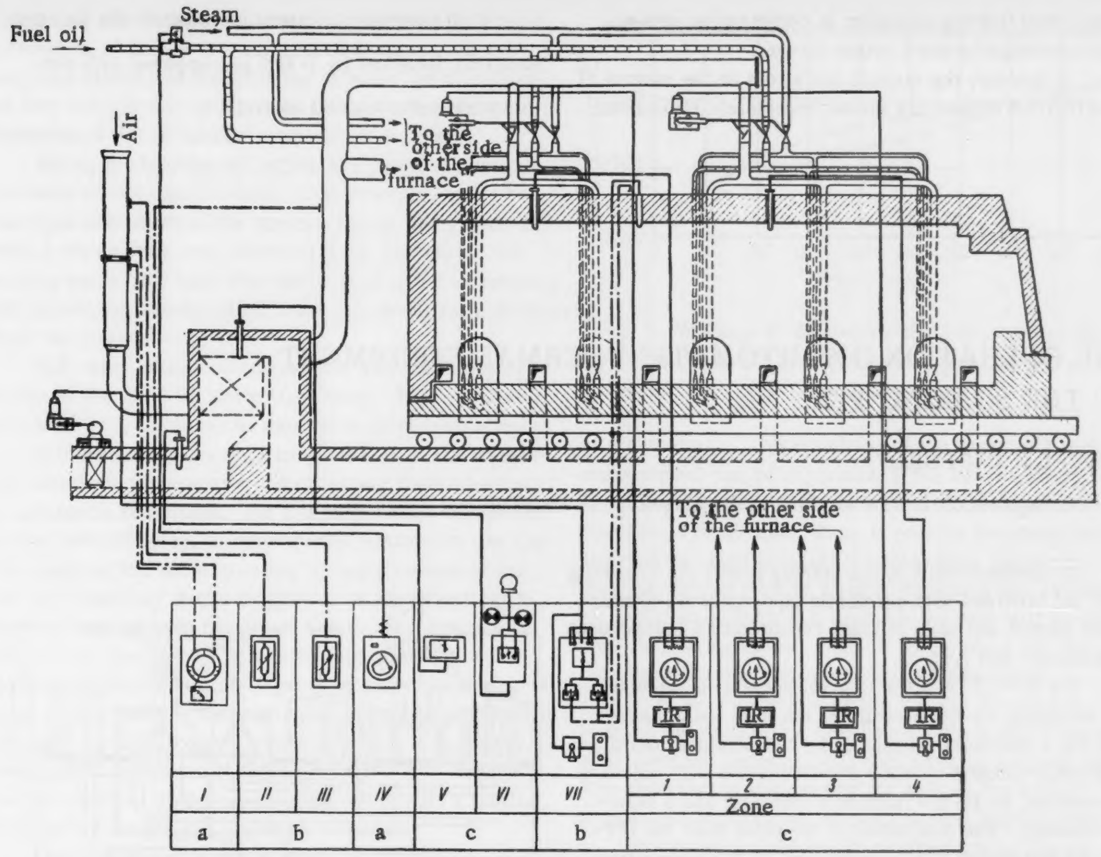

Fig. 2. Diagram showing a system of temperature measurements, and automatic control of a chamber furnace: I) Air from the air blower; II) air to the recuperator; III) air from the recuperator; IV) fuel oil; V) waste gases from the recuperator ; VI) overheating of the element of the recuperator; VII) working space of the furnace: a) flow rate; b) pressure; c) temperature.

mocouple makes it possible to reduce the time lag and the time constant substantially (in comparison with the thermocouple with an additional protecting carbofrax sheath).

The temperature in the working space of the furnace is maintained to an accuracy of ± 10 °C.

The ratio of oil-to-air-to-steam is controlled separately for each zone of temperature control. Each zone has a distribution lever to which the mechanisms operating the controlling instruments on the fuel oil feed line, air line, and steam line are connected. In order to ensure the necessary air ratio (α=1.15 during the heating period and α = 0.95 during the soaking period) when coupled control valves are used, one must have constant parameters of the controlling elements. When the temperature regulator sends out the pulse for changing the oil rate, then, at the same time, the air rate and the steam rate are changed so that the ratio remains constant.

The unit for the automatic control of the air-to-fuel-to-steam ratio is set up in the following way. The characteristics of one of the three controlling instruments is determined. For this purpose one determines, for instance, the oil flow rate at various settings of the controlling valve. Then the characteristics of the remaining controlling instruments are found, but, at the same time, for each of the controlling instruments several characteristics at various positions of auxiliary valves located at the burner (the additional valves also serve for the uniform distribution of fuel, air and steam to the burners, Fig. 2) are determined. From the characteristics obtained, one selects those which are similar to the characteristics of the oil valve. The change in the ratio is effected by varying the position of the levers which connect regulating instruments with the distribution lever. With this setup, the maximum flow (of oil, air and steam) should be approximately one and a half times the normal value. If the initial adjustments are carried out correctly, this control system of the ratio can operate quite satisfactorily and is, at the same time, much simpler and cheaper than the control system operating with the ÉRS-67 regulator.

The pressure control in the working space of the furnace is usually effected by means of the RDM-35 in-

termittent floating controller in combination with a servomechanism and a rotary damper.

In this way the manual operations on the control of the thermal regime are almost completely eliminated.

With automatic temperature control, the fuel consumption decreases by 7-10% as compared with consumption under manual control.

* * *

THE OPERATION OF AUTOMATIC THERMAL EQUIPMENT AT THE SOAKING PITS

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All compartments of the soaking pits of the blooming mill are provided with automatic equipment for temperature control and each of them constitutes an independent operational unit (Fig. 1).

The ÉPP-120 electronic potentiometer is intended for recording the temperature of the steel being heated and has a resistance transducer for temperature control. The potentiometer operates in conjunction with radiation pyrometers, an IR-130 isodromic regulator and a servomechanism. The magnitude of the pulse from the ÉPP-120 potentiometer varies, depending on the temperature of the ingots being heated in the compartment.

By means of the radiation pyrometers, one can measure the temperature of the ingots at the near side as well as at the far side of the pit. This is very important since until now in recuperative soaking puts one has only measured the temperature of the combustion products in the top part of the pit by means of a thermocouple and from this reading the temperature of the ingot has been determined.

Measurements of the temperature of the ingot in regenerative soaking pits by the method described above are more accurate in the range from 1300 °C upward (Fig. 2) when the readings of the radiation and the optical pyrometers coincide.

Owing to the accurate measurement of the temperature, one can bring the temperature of the ingots near the melting temperature of the scale and this is conducive to an increased throughput of the blooming mill, an improvement in the heating of the steel and in the plastic properties of the steel and a reduction in the metal losses.

Investigations have shown that the loss of metal in burning during the reheating of 7 ton ingots of rimmed steel constitutes 0.67-0.93%, so that with the present throughput of the mills an increase in metal loss in burning would constitute a substantial loss per annum.

The isodromic regulator, IR-130, is intended for the control of the temperature regime preset by the welder.

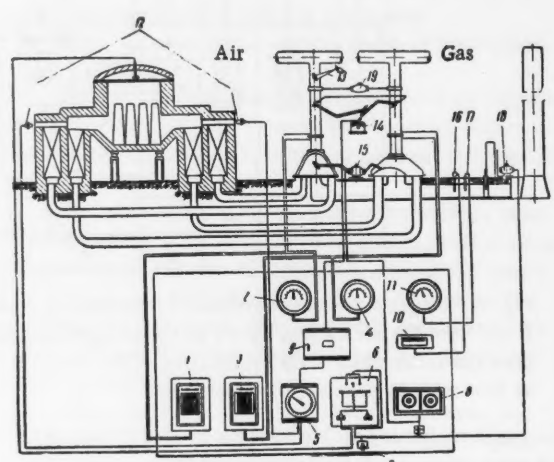

Fig. 1. Diagram showing the automatic temperature control system of the soaking pits at the blooming mill: 1)2) recording and indicating flowmeter for air; 3)4) same for gas; 5) electronic potentiometer for recording the temperature of the ingot surface; 6) regulator of the pressure in the compartment (RDM-35); 7) universal switch; 8) motor time relay for automatic valve change; 9) IR-130 isodromic temperature regulator; 10) indicating galvanometer for measuring the flue gas temperature before the damper; 11) indicating manometer for measuring the pressure before the damper; 12) radiation pyrometer for measuring the temperature of the ingot surface; 13) air-control throttle valve; 14) servomechanism for gas and air supply; 15) electric motor for valve change; 16) thermocouple for measuring the temperature of the flue gases before the damper; 17) pulse tube for measuring the pressure before the damper; 18) electric motor and silent electric hoist for the damper; 19) gas and air cutoff.

Gas-to-air ratio regulators have been replaced by a rigid connection of the gas and air throttling valves. In this way, one eliminates the time lag between the change of air rate and gas rate which caused irregularities in the operation of the automatic temperature control.

During the heating-up period, the gas-to-air ratio is the same for all types of steel. Consequently, owing to the rigid connection of the throttle valves, the gas-to-air ratio is set up for a long period of time, and during the soaking period this ratio can easily be changed by rotating the air control throttle valve if the gas-to-air ratio deviates from the preset value.

The valve change is carried out automatically by means of the MRV-26 motor time relay. This automatic unit is reliable in operation and works quite satisfactorily.

If there are temperature irregularities in the regenerator checkers, the operator can eliminate them by means of automatic equipment. For this purpose one can preset, on the MRV-26 relay, a longer period of time for gas and air supply on the hotter side and a larger amount of gas and air depending on the magnitude of the deviation in the temperature from the preset value. The increase in gas and air input results in a more rapid cooling of the overheated checkers of the regenerators, and an increased input of fuel and gas forms a larger amount of combustion products which heat up the cooler checkers of the regenerators on the opposite side rapidly. On the side of the coolest checkers of the regenerators one presets a shorter time period for gas and air input.

Owing to the different amounts of gas and air which enter the checkers of the regenerators through the far side and near side, and owing to the various time lengths for their input, the temperature irregularities appearing in the regenerator checkers are eliminated and thus norma conditions for steel heating and for soaking pit operations are established.

The pressure control in the working space of the soaking pit is effected by means of the RDM-35 regulator.

Gas and air cutoffs are provided for each soaking pit to facilitate the work of the crane operators at the soaking pits and to save fuel. When the cover of the soaking pit is moved up one meter, the gas and air throttles are closed and the gas and air supply to the pit is cut off.

Temperature irregularities in the checkers of the soaking pit regenerators impair the quality of metal heating and reduce the service life of the regenerator.

When a correct system is selected for the temperature control, the disadvantages connected with the nonuniform temperature of the checkers of the regenerators are eliminated. For this purpose, the valve-change system includes provision for switching radiation pyrometers for every valve change so that the temperature is always measured on the side of the outgoing combustion gases, i.e., on the hottest side. This is very important, since in this way the maximum temperature in the pit is measured and temperature irregularities in the checkers of the regenerators are eliminated without the intervention of the operator. This operation of the automatic temperature control can be explained in the following way.

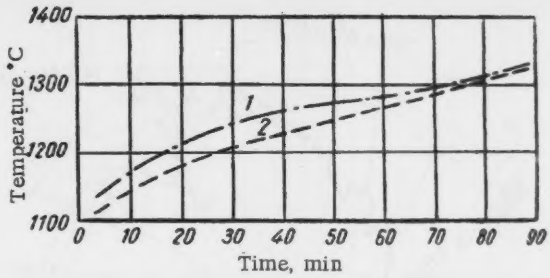

Fig. 2. Readings of the radiation (1) and optical (2) pyrometers during the heating of ingots charged at a temperature of 650 °C into the soaking pit.

If we assume that the near side of the regenerator checkers is overheated, then, as soon as the preset temperature of the ingot is reached on that side, the servomechanism will receive a signal to reduce the gas and air input, since from that moment the heat will be used only for heating up the interior of the ingot and for compensating the heat losses to the surroundings.

From the moment when the gas and air input is reduced the regenerator checkers which, at that time are at a lower temperature, will cool down at a slower rate. The reduction in the gas and air input to the hotter regenerator checkers prevents them from getting overheated.

As soon as the valves are changed again, the gas and air enter on the hotter side of the regenerator checkers and the temperature is measured by the radiation pyrometer on the cooler side, then the servomechanism will receive the signal to increase the gas and air rate and hence the overheated regenerator checkers can be cooled more rapidly while the temperature of the cooler regenerator can be raised.

In this way, owing to the technically sound system of switching the radiation pyrometers, temperature irregularities of the regenerator checkers can be eliminated by the automatic system itself as soon as the predetermined temperature of steel is attained. In addition, this method helps in improving the heating process of the steel, eliminates a premature breakdown of the regenerator checkers caused by high temperature irregularities and increases the service life of the regenerator checkers (to 3-5 years).

Figure 3 shows the usual temperature conditions during the manual control of steel heating in the soaking pits; the time of heating was 65 minutes longer than with the automatic control. The temperature fluctuated between 1390 and 1270 °C.

It is almost impossible to maintain the preset temperature of the steel by means of manual control and, hence, large temperature changes are unavoidable; this is very harmful to the quality of the metal heated and results in excessive fuel consumption. The metal loss

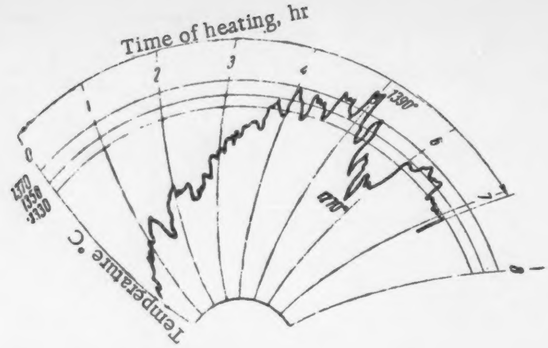

Fig. 3. Temperature recordings during the heating of cold-charged steel. Time of heating: 7 hr 15 min.

will also be considerably higher than during the operation with automatic control.

A particular feature of the operation of the automatic temperature control system is the fact that the temperature preset by the operator is achieved quickly and then is maintained automatically until the ingots are discharged from the pit. In this way, favorable conditions for a uniform heating of the interior of the ingot are established.

The application of automatic temperature control made it possible to reduce the time period of steel heating to $1^1/_2$ -2 hr, to reduce the temperature of heating (since the soaking period could be made longer) and to obtain ingots at a uniform temperature for rolling.

At present, the production of radiation pyrometers is still very inadequate although the advantages over thermocouples in measurements of the temperature of ingots are quite obvious.

When the soaking pits at our Factory were operated with the automatic temperature control system, the consumption of refractories and fuel was substantially reduced and the operating efficiency of the furnace attendants increased. In one shift, a furnace attendant delivers an average of 1060 tons of steel and some attendants deliver up to 1400 tons; one attendant operates three groups of soaking pits with 8 compartments each; 9750 tons of steel are heated annually per square meter of live pit-hole area.

The amount of overheated metal during 10 months of 1958 amounted to 105 g per ton of heated metal.

For a further improvement in the efficiency of soaking pits it is necessary:

1) to tighten the covers of the soaking pits and thus improve working conditions for the operating personnel; to reduce fuel consumption by 4%; to reduce the time of heating and the consumption of refractories and covers (annual savings would amount to 500,000 rubles);

2) to introduce remote control of the soaking pit covers by means of grab cranes and consequently to reduce the number of assistants to furnace operators by half and to release these workers for other duties;

3) to master the removal of slag from the soaking pit bottoms in the course of metal heating and thus to increase the output of the pits by 5%.

MULTILAYER SINTERING OF A NEW HEARTH BOTTOM IN OPEN-HEARTH FURNACES

I.A. Bedrik

The 85-90 ton open-hearth furnaces of the Alapaevsk Metallurgical Combine have magnesite-chromite roofs and are fired with producer gas and fuel oil. In 1958, a new method of sintering the bottom after major overhaul of the open-hearth furnaces was introduced at the Combine. Experiments carried out at the Serov Metallurgical Combine confirmed the advantages of the new method for sintering the hearth bottom in basic open-hearth furnaces.

The composite method of sintering the bottom consists of the following:

The sintering operation is started at the maximum temperature of the furnace; the temperature of the roof should be 1640-1690 °C and the temperature of the checkers not less than 1180 °C. Before the first layer is sintered in, the brickwork of the bottom and of the banks is treated with scale from rimmed steel. Before the scale treatment, the tapping hole is temporarily plugged. The scale is spread uniformly over the whole of the bottom over the banks and the parts of the front and rear walls adjoining the bottom. Usually, half as much scale is used for the banks and the walls as for the bottom. If the amount of scale introduced during the first operation is found inadequate, more scale is added.

After the scale has been melted with the use of compressed air delivered by tubes, it is spread over the whole of the bottom, the banks and the front and rear walls. This operation is repeated until a fairly large amount of liquid slag collects on the bottom near the tapping hole and the bottom acquires a lustrous appearance. After the liquid slag has been kept in the furnace for 1.5 hr, the tapping hole is opened and the slag which has not been assimilated by the bottom is run off.

The first sintered layer, 25 – 30 mm thick, consists of magnesite powder which should contain at least 87% MgO and consist of grains 3-7 mm in size. Therefore, the powder is first screened through a screen with 2 mm openings and then through a screen with 6 mm openings. The layer is heated thoroughly at a roof temperature of 1650-1690 °C until a continuous layer is formed. Samples are taken from this first layer by means of a steel tube in order to determine how efficiently the layer has been sintered. A well-sintered layer has a dark-grey color and adheres easily to the tube.

The second layer, 15-20 mm thick, consists of a mixture of powder and scale (15-20% by weight of magnesite) and is heated in the same way as the first layer. The third layer, 15-20 mm thick, is applied in the same way as the second. After 3 layers have been sintered, the fourth layer is applied and is used to smooth the contour of the bath, and then the furnace is heated for 2 hours. The bottom and the banks are then covered with scale. Any liquid slag and scale which has accumulated near the tapping hole is run off and the tapping hole is closed in preparation for the first heat.

The multilayer sintering of a new bottom can be accomplished in 30-35 hours. Previously, the sintering of the bottom took 100-140 hours.

* * *

THE OPERATION OF A BASIC BESSEMER CONVERTER WITH OXYGEN-ENRICHED BLAST

The main disadvantage of the cheap highly productive processes of steelmaking in Bessemer and Thomas converters – a lower quality of steel in comparison with open-hearth steel and electric-furnace steel – has been successfully overcome in recent years by means of changing the method of smelting the steel whereby a reduction of harmful contaminations, first of all of nitrogen, in steel is accomplished. In open-hearth and electrically made steel the nitrogen content constitutes approximately 0.005% and in ordinary converter steel it constitutes 0.016%. Together with phosphorus, nitrogen prevents the production of plastic steel for deep drawing and wire production.

In Central European countries, (Germany, Belgium, Luxembourg, France) where, as a result of large supplies of high-phosphorus ores, the main steelmaking process is the Thomas process, methods are being developed which would permit the production of steel in a Thomas converter with qualities approaching those of steel made in open-hearth furnaces or electric furnaces. We give below a description of one variation of the Thomas process. In Western Europe the converter for this process is called the oxygen converter (oxy-Thomas Converter)

It is known that as long as the carbon content in the steel which is blown through in the converter does not fall below 0.5%, the relatively high partial pressure of carbon oxides in the gas phase above the metal surface prevents any increase in the nitrogen content in the steel. If one interrupts the air blast when the carbon content in steel is reduced to 0.5% and begins to blow pure oxygen then the final steel will have a very low nitrogen content – approximately 0.004%. Several factories, however, prefer to use air blast enriched with approximately 35% oxygen.

The advantage of this method lies in the fact that one can charge a certain amount of hard charge materials, i.e., scrap, ore, rolling-mill scale, etc., into the converter. The reduction in the nitrogen content in the steel will then be smaller than in the previous case since during the removal of phosphorus from the steel the partial pressure of nitrogen in the gas phase in the converter will inevitably increase. A partial reduction in the nitrogen content in steel is achieved by charging iron ore or scale into the converter. In addition, the enrichment of the blast with oxygen increases the temperature in the tuyere zone; the tuyeres are rapidly damaged and the service life of the bottom is shortened. The temperature can be reduced to some extent by charging scrap and iron ore into the converter before the blowing period. Some plants also use oxygen diluted (during the blowing) with carbon dioxide or steam; the latter must be dry (superheated) in order to prevent the absorption of moisture by the dolomite bottom of the converter. The disadvantage of this process is that it tends to produce low-carbon steel and cannot produce medium-and high-carbon steels since the phosphorus is removed from the steel after the removal of the carbon.

Below, we quote some typical operating statistics of this process*.

Capacity of the converter: 45 tons. Chemical composition of the initial blast-furnace pig iron: 3.5% C; 1.8% P; 0.40% Si; 0.42% Mn; 0.050% S. Composition of the final steel: 0.05% C; 0.040% P; 0.1% Mn; 0.03% S; 0.009% N. Composition of the converter slag: 18% P_2O_5; 5% SiO_2; 50% CaO; 8-10% FeO; 4% MnO. Temperature of the steel when poured: 1570 °C; total duration of the heat: 25-30 min ; duration of the blowing period: 12-14 min . Consumption (based on the yield of steel ingots) of iron ore – 3%; of scrap – 6%; of lime – 12%; of oxygen – 20.5 cu.m. Yield of acceptable ingots 87%. Oxygen pressure: 3 atm; oxygen content in the blast: up to 30%. Rate of carbon loss: 0.35% C per min ; service life of the lining: 60 heats; dolomite consumption: 11.8-13.2 kg/ton of ingots. Lining repairs take 2 days; replacement of the converter bottom – 7 hours. Capital expenditure amounts to 75% of the expenditure required for an open-hearth furnace of the same capacity.

* A.G. Raper and K.H. Hoyle, Iron and Steel, 31, 11, 499 (1958).

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CONVERTER STEELMAKING BY MEANS OF BLOWING-IN LIME DUST WITH THE OXYGEN BLAST

The low velocity of several metallurgical processes is due to insufficient contact area between the reacting substances, one of which is the liquid metal and the other – slags, fluxes, etc. Several improvements in metallurgical processes have been suggested in recent years with the object of establishing a close contact between the liquid metal and the slag. These improvements include: the electromagnetic mixing of steel in electric-arc furnaces; blowing the gas through a porous brick into the molten metal; blowing pulverized lime into the molten metal, etc. The work of the French Research Institute of Metallurgy (Irsid) on the treatment of high-phosphorus pig iron in the Thomas converter is of great interest*.

A blind-bottom converter with dolomite-and-tar rammed lining was used. The working volume of the converter was 1.5 m^3 or 0.5 m^3/ton of pig iron; in ordinary Thomas converters this figure is approximately 1.2-1.5 m^3, and in oxygen converters - 1 m^3. The oxygen lance could be move vertically above the bath; the water consumption for cooling the lance was 20 m^3/hr. By means of a special distributor – a screw batcher – inserted in the oxygen main near the tuyere, the required amount of line, ground to a particle size of 1 mm, was introduced into the oxygen stream. The total lime input constituted 400 kg/heat; quicklime contained 86-92% CaO, 1-1.5% SiO_2 and 0.07-0.12% S.

Pig iron used for the process contained 3-3.9% C; 0.15-1.0% Si, 1.7-2.0% P, 0.3-0.7% Mn and 0.008-0.120% S. 99.5% pure oxygen was supplied under a pressure of 15 atm. Swedish ore containing 57% Fe, 2% CaO, and 10% SiO_2 was used for cooling the metal in the converter; at the beginning of the blowing, iron ore of up to 1 mm particle size was used. In the course of the blowing, lumpy ore (of particle size up to 20 mm) was used.

During the first period of blowing (12-15 min), 67% of the required oxygen and ground lime was introduced into the converter. As the temperature rose to 1600 °C a freely flowing slag was obtained. In spite of the low iron content (about 5%), the slag contained more than 20% P_2O_5, it was running off easily, and dissolved readily in citric acid. The second period of blowing lasted for 9-10 min and could be completed, if required, to produce a very mild steel at a temperature of approximately 1650°C. By running off the slag at the end of the first period of blowing, it was possible even at this high temperature to obtain steel with a phosphorus content below 0.025%.

The oxygen input during the first blowing period was 128 m^3 (43 m^3 per ton of pig iron); the lime input was 250 kg (83 kg per ton of pig iron). The oxygen input during the second blowing period was 66 m^3 (22m^3/ton of pig iron); the lime input was 170 kg (57 kg per ton of pig iron). The total consumption of oxygen and lime constitutes, respectively, 65 m^3 and 140 kg per ton of pig iron.

When 90% of the phosphorus was removed from the steel phosphorus content was reduced from 1.8 to 0.18%), the carbon content in the bath decreased by only 60% – a reduction from 3.57 to 1.45% (during the first blowing period). At the first turn of the converter, the steel contained 1.45% C; 0.18% P and 0.023% S; at the second turn of the converter (1630 °C) it contained 0.04% C; 0.016% P; 0.018% S and 0.001% N_2.

The experimental heats proved the effectiveness of the process; it ensured that overoxidation of the steel did not occur. The efficiency of desulfurization was 70% (as compared with 40-50% in the ordinary Thomas process). An indirect indication of the reduction in dolomite consumption is the fact that the content of magnesium oxide in the intermediate and final slags did not exceed 1%.

From the results of the mechanical testing of the steel, it was concluded that the new process is suitable for producing steel of a quality not inferior to open-hearth steel and suitable even for deep drawing.

I.R.

* Revue de Metallurgie 55 p. 1, 68-74 (1958).

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New Books

G. Koppenberg and V. Ventsel'. Metallurgical Processes in a Shaft Furnace Operated with Oxygen Blast. (Translation from the German by K.V. Messerle). Moscow, Metallurgizdat. 1958, 157 pages.

The book by the German scientists, Koppenberg, and Ventsel' deals with the application of oxygen in shaft furnaces. After presenting a detailed analysis of the thermodynamic principles of the application of oxygen and explaining the theory of the metallurgical processes in shaft furnaces, the authors pass to the practical results of the operation of furnaces with the use of oxygen-enriched blast. A description of the design of low-shaft and shaft furnaces and of the technology of the processes in these furnaces is given.

The book will be of great interest to engineers in blast-furnace shops and will be useful for research workers in institutes and industrial laboratories.

A.G.

G.M. Borodulin. The Use of Oxygen in Electric Steelmaking. Moscow Metallurgizdat, 1958, 87 pages.

In his booklet, G.M. Borodulin describes in detail experience on the use of oxygen for steel production in electric-arc furnaces. At the beginning of the book, methods of supplying oxygen to the electric furnaces are described. Then the methods of using oxygen for speeding up the melting of the charge and the decarbonization of the metal are presented. The production of steels of various grades (stainless, high-speed steel, ball-bearing steel and others) with the use of oxygen is described in detail. A separate chapter is devoted to the quality of electrically made steel produced with the use of oxygen. The booklet contains operating statistics of the steelmaking process, and a description of the methods of mechanizing the work of the steel melters and improving the safety precautions during the production of steel in electric furnaces with the use of oxygen.

The booklet may be useful for engineers and foremen in electric steelmaking shops and for university students.

A.G.

I.I. Sinitsa. Two-Side Periodic Sections (Design). Moscow Metallurgizdat, 1958, 46 pages.

The booklet presents the experiences of the Petrovskii Factory on mastering the production of periodic sections. The design of periodic sections which are produced by means of longitudinal rolling is discussed. Difficulties in mastering the production of these sections due to the large changes in the cross-section area over the length of one period of the rolled piece are described.

The booket contains a description of methods of rolling periodic sections in free-spread passes and in passes with partially limited spread. The design of two-side periodic sections of simple and special shapes and of constant-width sections is described. The book contains the permissible tolerances in the dimensions and examples of design calculations for periodic sections.

The booklet is intended for technical personnel of iron and steel factories engaged in the production of periodic sections.

S.S.

F.L. Panasenko. The Rolling and Thermal Treatment of Thick Plates. Moscow Metallurgizdat, 1959, 155 pages.

The book contains a description of the technology of the production of thick plates from carbon and alloy steels; a description and the operating statistics of modern two-stand tandem mills, and of semicontinuous and continuous plate mills are given; methods of removing surface defects from ingots and slabs, of heating metal in continuous reheating furnaces and the plastic properties of steels are described; an account is given of methods for the removal of scale from the surface of plates in pickling machines and for the mechanical removal of scale by shot-blasting.

A separate part of the book is devoted to the thermal treatment of thick plates of carbon and alloy steels in batch furnaces with removable hearth, in bell-type furnaces, and in continuous roller-hearth furnaces. The continuous-flow methods of the thermal treatment of plates are described.

The book is intended for technical personnel of iron and steel factories and can be useful for the designer of new shops and plants for the production of thick plates.

S.S.

G.A. Khoroshikh. The Operator at the Tube-drawing Mill. Sverdlovsk Metallurgizdat 1958. 176 pages.

At the beginning of the book a very short account of the main physical and chemical principles is presented. A more detailed account of the methods of rolling tube billets and a description of the equipment in tube-drawing mills are given; the description of the tube-drawing process includes the following: the preparation of the billet for drawing, the pickling of the tubes, lubricating the tubes during drawing, methods of lubricating the tubes, case hardening and drawing. Design calculations for cold drawing, as well as the thermal treatment, finishing operations and acceptance of tubes are presented.

This publication is a textbook for the education of workers at tube-drawing mills and it can also be useful for team leaders and foremen at tube-drawing mills.

S.S.

S. Akhmatov. The Iron and Steel Workers and the Miners are Adopting Advanced Techniques. Moscow, Profizdat, 1958, 71 pages.

This booklet gives an account of the achievements of the iron and steel workers from Dnepropetrovsk and Dneprodzerzhinsk, and of the miners of the Krivoi Rog Basin who followed the initiative of the famous Donets miner, Nikolai Mamai.

G.I. Lednyanskii, the leader of the Komsomol Youth Team at the Lenin Factory, proposed that in each shift an additional output over and above the quota should be achieved from the steel which is saved. According to his calculations, his team can produce 5 km of tubes over and above the quota in a year. The booklet also describes the plan for the full automation and mechanization of the electrowelding shop at this Factory, the meeting of Nikolai Mamai and the workers of Dnepropetrovsk, the competition between the Dzerzhinskii Mine and the miners of the Krivoi Rog Basin to prepare stock of iron ore over and above the planned quota for new blast furnaces.

The booklet also describes how the trade union organizations at industrial establishments help in the dissemination of any new techniques which are conceived in the competition for more than fulfilling the production quota in every shift.

S.S.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosénergoizdat	State Power Engr. Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LÉIIZhT	Leningrad Power Inst. of Railroad Engineering
LÉT	Leningrad Elec. Engr. School
LÉTI	Leningrad Electrotechnical Inst.
LÉTIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MÉP	Ministry of Electrotechnical Industry
MÉS	Ministry of Electrical Power Plants
MÉSÉP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTi	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOÉ	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIÉL	Central Scientific Research Elec. Engr. Lab.
TsNIÉL-MÉS	Central Scientific Research Elec. Engr. Lab.-Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIÉSKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Meteorology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZÉI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us - Publisher.